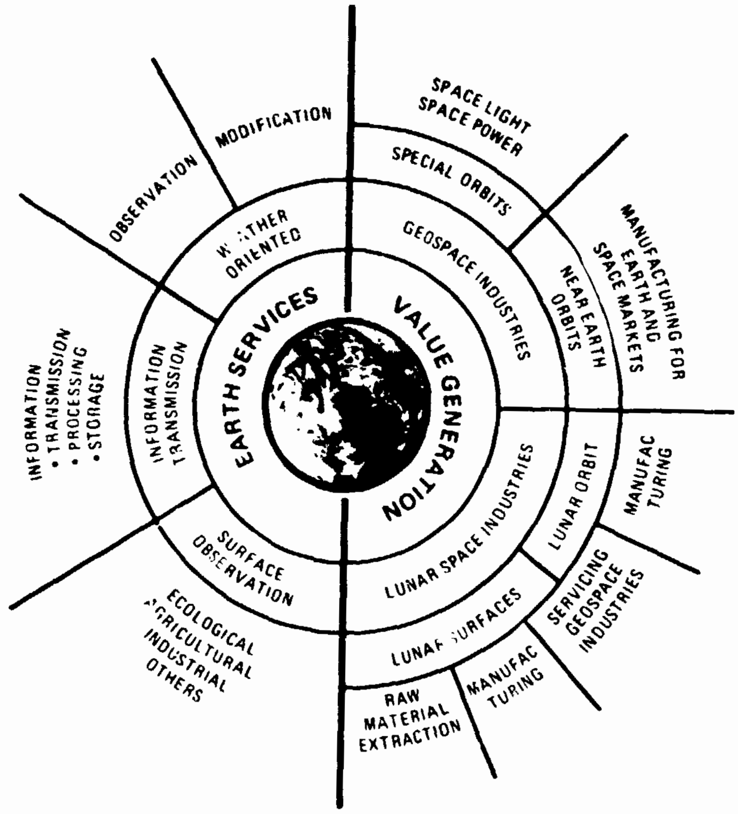
SD-78-AP-0055-4

Space Industrialization



APPENDIXES

FINAL REPORT

Rockwell International
Space Division

(NASA-CR-150723) SPACE INDUSTRIALIZATION. VOLUME 4: APPENDIXES Final Report (Rockwell International Corp., Downey, Calif.) 528 p HC A23/MF A01 CSCL 22A

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FOREWORD

This $190,000 Space Industrialization Study was performed under NASA Contract NAS8-32198 for Marshall Space Flight Center from September 1976 through April 1978. The study was in two parts: Part 1 identified the potential goals for space industrialization and developed and assessed evolutionary program options for realization of those goals; Part 2 defined program support demands, evaluated and defined the leading program options, and developed recommendations for program implementation. The study results are documented in four volumes:

1. Executive Summary
2. Space Industrialization Background, Needs, and Opportunities
3. Space Industrialization Implementation Concepts
4. Appendixes

The Rockwell study manager was Mr. C.L. Gould. Other key Rockwell participants were A.D. Kazanowski and T.S. Logsdon. Additional support was provided by D.B. Anderson, C.R. Gerber, and T.A. Sackinger. Many others helped in various ways. They included the following key consultants:

- Dr. Krafft Ehricke
  Space Global, La Jolla, CA
- Dr. Reed Powell
  California Polytechnic University,
  Pomona, CA
- Dr. Charles Cheeseman
  General Electric,
  Valley Forge, PA
- Dr. Ernst Stuhlinger
  University of Alabama,
  Huntsville, AL
- Dr. Gerard O'Neill
  Princeton University, Princeton, NJ
- Dr. Delbert Smith, J.D., Space Law
  Madison, WI
- Dr. Kerry Joels
  NASA/Ames Research Center, CA

The study was performed under the technical direction of C.C. Priest, Marshall Space Flight Center. Mr. J. von Puttkamer was the overall program manager at NASA Headquarters, Office of Space Transportation Systems. Major contributions were also made at special working group meetings by the following:

- Andrew Adelman
  IBM
- Dr. Bertrand Chatel
  United Nations
- Debbie Donahue
  President, Student Chapter of AIAA,
  University of California at Irvine
- Bonnie Dunbar
  Rockwell International
- Fredrick Durant III
  Smithsonian Institution,
  Air and Space Museum
- Clarence Hill
  Rockwell International
- Barbara Marx Hubbard
  Committee for the Future,
  Washington, D.C.
- Walter Morgan
  Comsat Corporation

Inquiries regarding the study should be addressed to the following:

- Claude C. (Pete) Priest
  NASA-Marshall Space Flight Center
  Attention: PS04
  Huntsville, AL 35812
  Telephone: (205) 453-27?6
- C. L. (Chuck) Gould
  Rockwell International
  12214 Lakewood Boulevard
  Downey, CA 90241
  Telephone: (213) 594-3560

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A. STUDY APPROACH AND WORK BREAKDOWN STRUCTURE

APPENDIX A

STUDY APPROACH AND WORK BREAKDOWN STRUCTURE

STUDY APPROACH AND WORK BREAKDOWN STRUCTURE

The complex task of looking 50 years into the future and determining a recommended approach to the industrialization of space is presented in an overview form in Figure A-1. We undertook the task with humility and do not pretend to take fully into account all the socio-economic, technology, and politics of world wide earth and infinite space.

Our work started with two parallel paths: one looking into the future for trends and needs and the other searching for space opportunities that technological forecasting could foresee. Previous work on both subjects is voluminous and we read most of it. The problem was to get from the general to the specific and from the infinite to a reasonable approach that could be understood and supported. Two kinds of screening were used, a narrowing process that identified the best of the opportunities and an integrating process that allowed a very few directions of hardware/technology flow to accomplish multiple opportunities and bring about their benefits.

The direction we want to head and the pace at which we want to proceed are critical to the process. Fundamental to both is the age-old question of major attention to immediate needs versus the foresight to sacrific some of today for a better tomorrow. Also fundamental is the possibility of a major event -- like a war, climate change, end-of-aging drug, etc. We postulated six program options, four based on immediate crisis response and foresight and one on climate change hurting the northern hemisphere. Another program option was based on commonality across the other five.

By the time you consider six program philosophies, 60 opportunities, three ratings of importance, and five ratings of rate -- all divided into five time frames, you can get about 5000 separate decisions for each option. We made these and exposed at least 100 people into the results -- in complicated reports and extended working group sessions. Their response and our judgment led to the preliminary results summarized in the main body of this report. In addition, a preliminary hardware implementation scheme is shown, based heavily on full utilization of the Shuttle, minimum cost over the whole time period considered, and driven heavily by the steps we need to take to make critical energy decisions in the next few years.

At the end of Part I, Rockwell and SAI had each developed various individual program options for the future space industrialization program. Up to this point the efforts of the two contractors were purposely kept separate so that the various opportunities for the industrialization of space could be studied to a reasonable level of detail from two distinct viewpoints. However, at the end of Part I of the study it seemed more appropriate to merge these two efforts into a single concentrated assault for Part II. Accordingly, a series of meetings was held in which Rockwell, SAI, and NASA representatives developed a new set of program options combining elements from the options which has been developed separately in Part I.

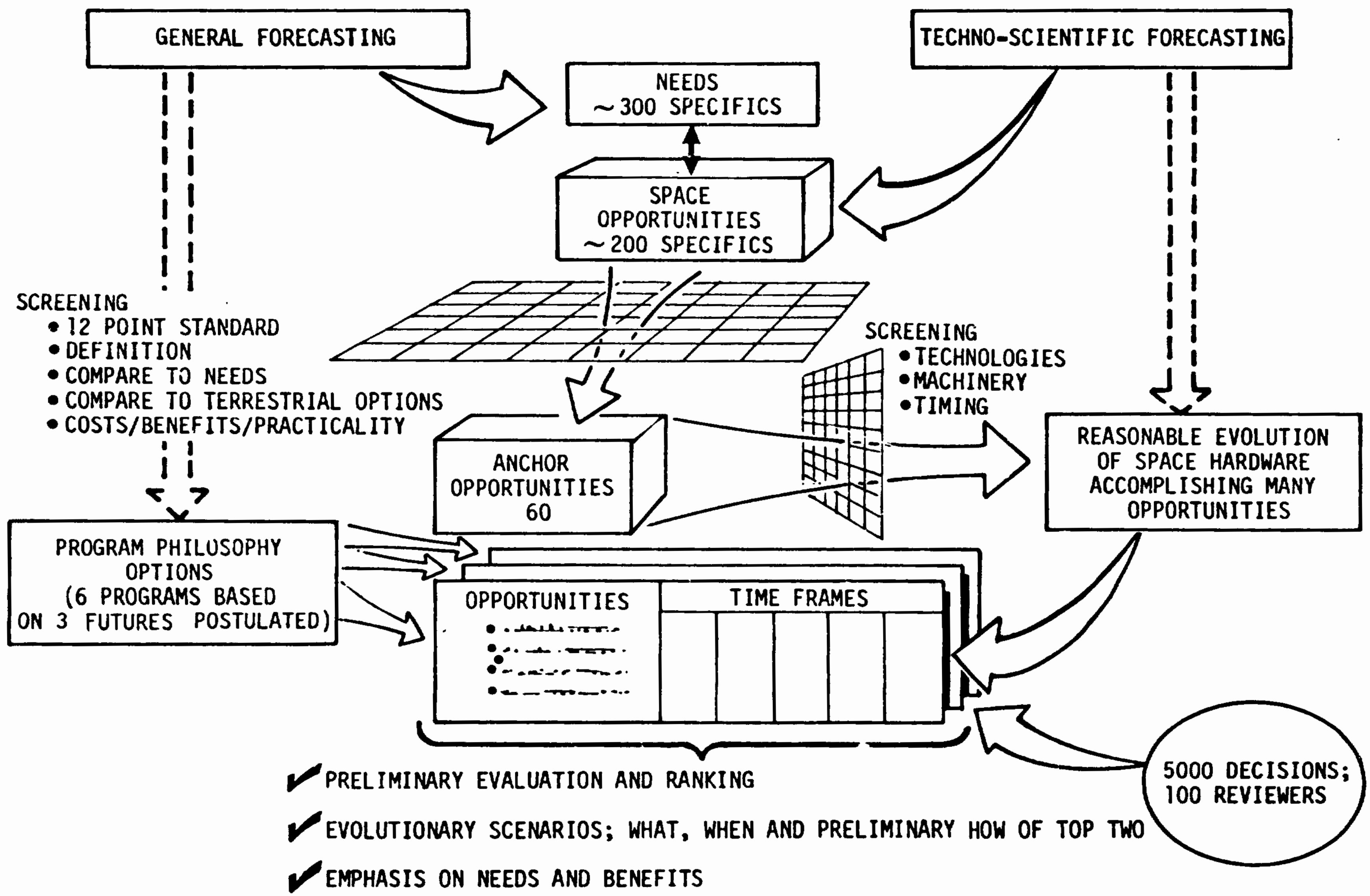


Figure A-1. Rockwell Space Industrialization Part 1 Logic Flow

As a result of these meetings three new program options were synthesized (See Figure A-2):

a. Energy program leadership

  a1. Emphasis on lunar materials

  a2. Emphasis on terrestrial materials

b. Energy program technology development only - implementation delayed until 1987 decision point

c. No major commitment to the development of the energy program (studies only)

As can be seen from this list, decisions regarding the energy options (particularly SPS) are fundamental to the scope and emphasis of the future space industrialization program. In particular, if either version of Option A is adopted, the program will be much larger and more ambitious than if the large-scale energy options are abandoned early in the program.

By mutual agreement most of the emphasis in Part II was placed on Option B, in which a firm SPS go/no go decision on the SPS was purposely delayed until 1987. Once these preliminary cooperative matters had been settled, the necessary hardware concepts were developed in sufficient depth to allow estimates of their weights and complexity levels; these estimates, in turn, were used in a series of cost estimating relationships to obtain fairly realistic time-phased cost estimates for the major elements in each program estimate.

With these designs and the resultant time schedules and cost estimates, it was possible to evolve a single sensible program of space industrialization that could be implemented and sold.

The salient features of this recommended program were then summarized in several different ways to encourage communication to a variety of groups. For example, a technically oriented program definition mode of communication was defined including work breakdown structures, costs and schedules, and necessary near-term technologies that would be appropriate for the technical community and aerospace professional. A mode of presentation centering on the societal benefits of the program would be more appropriate for government and industry leaders. And a mode of presentation oriented around the participation of various governmental agencies and other world agencies would be more appropriate for delivery to bureau chiefs and other specialized personnel.

WORK BREAKDOWN STRUCTURE

The initial work breakdown structure (WBS) used in this study is shown in Figure A-3. The work breakdown structure shows the elements costed. Cost estimates - both non-recurring and recurring - were developed for the space segment, ground segment, transportation, and operations for each of the recommended opportunities.

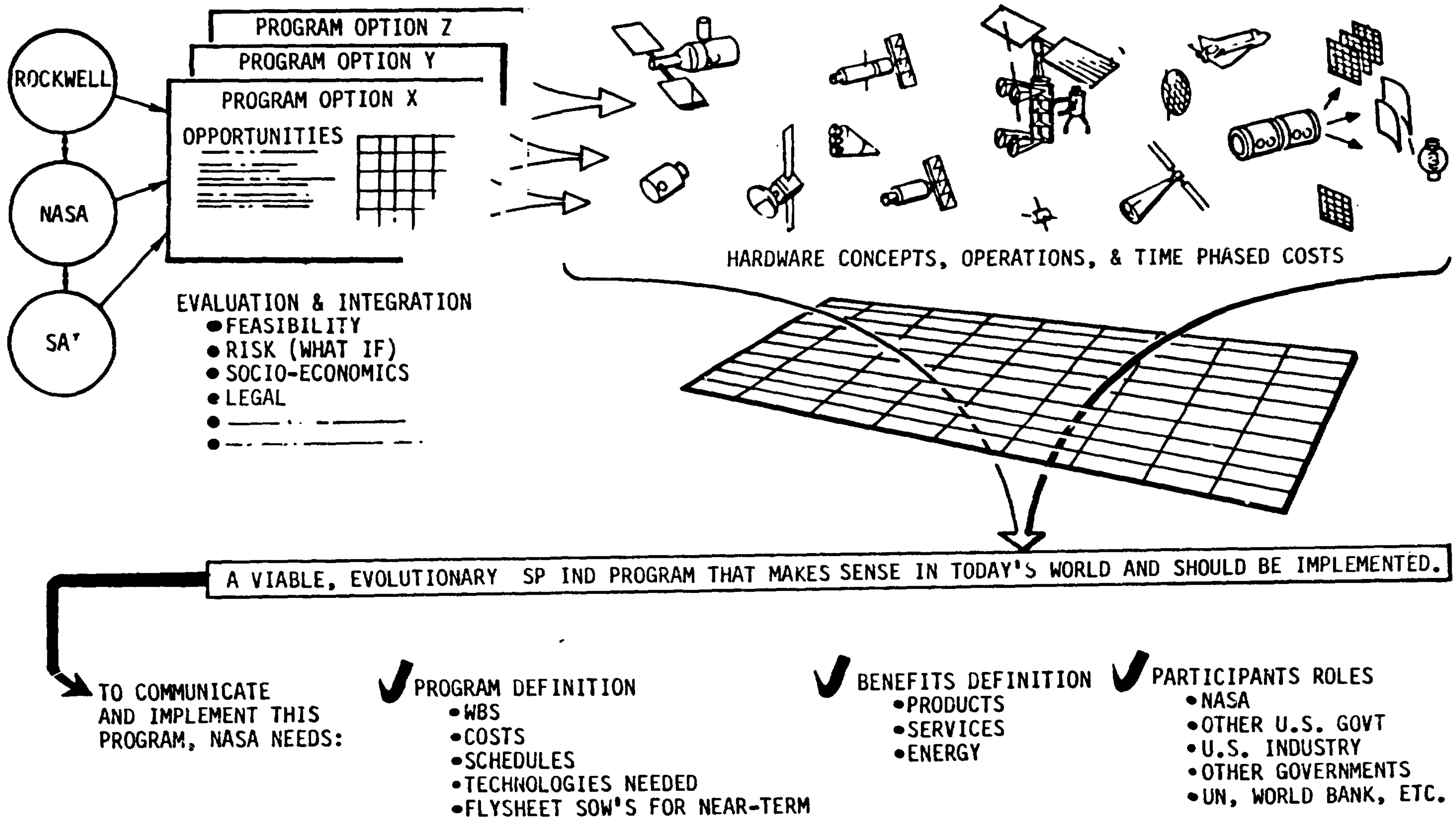
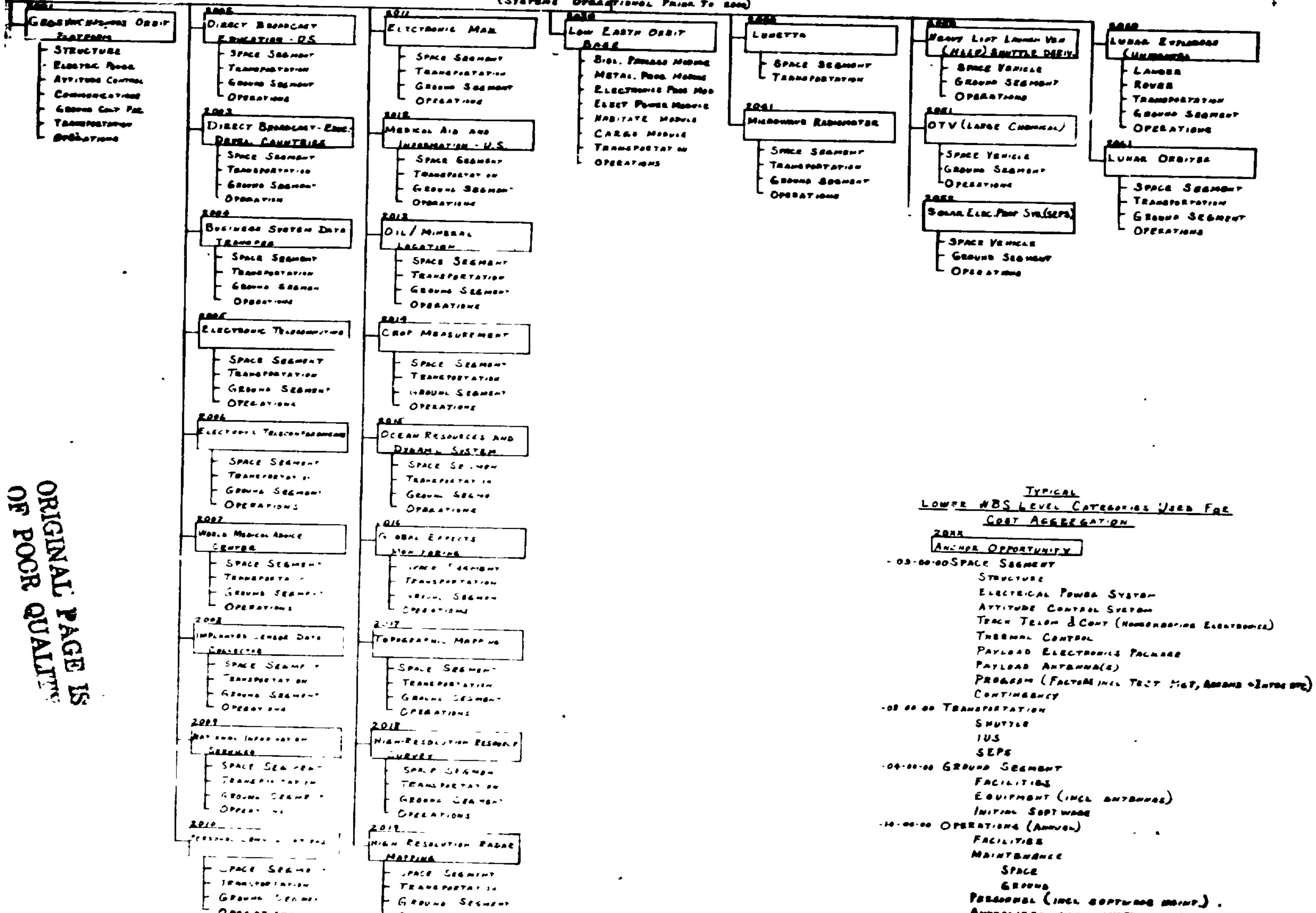


Figure A-2. Rockwell Space Industrialization Part 2 Logic Flow

Space Industrialization Program WBS ① - Plan B (WBS 2000-)

(Systems Operational Prior to 2000)



① Based on WBS format shown in Figure [illegible], WBS Matrix of Satellite Power System Work Breakdown Structure Dictionary IN-PP-76-1 MSFC, Nov 1976 ([illegible])

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B. NEEDS SUMMARY

APPENDIX B:

NEEDS SUMMARY

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NEEDS SUMMARY

Throughout the time interval in which the *background scenario* was being assembled, various needs of mankind were constantly being discussed by the members of the analysis team. However, actual work on the human needs section of the study was purposely delayed until the team members had an opportunity to digest and reflect on the background scenario and to develop clear notions on the probable course of various future large-scale human enterprises. The results of these thought processes are summarized in Tabl. 1 through 5. Note that the tables are labeled "Problem Solution Goals/Objectives." This rather devious title was selected to avoid a moot discussion of *real needs* versus *desires* that might result if the lists were more simply titled. Note also that time frames are assigned to each item. A short time frame corresponds to a need in the next decade. A medium time frame corresponds to a need in the late 1980's or the early 1990's and a long time frame corresponds to a need beyond the year 2000.

The needs listed in the various tables are divided into five separate categories:

1. Population
2. Industrial Production
3. Food
4. Energy
5. Political/Economic/Environmental

To some extent these categories were selected after the fact so that the various entries could be grouped for easier assimilation. Note that the structure and wording of the individual items in each list were influenced to some extent by the foreknowledge that this was a study of advanced space technology. In other words, the team members developed the various items in Tables 1 through 5. fully cognizant of the fact that the items listed were to be used to trigger further ideas on the potential uses of space to solve some of the problems of mankind. On the other hand, the lists were not strictly confined to those problems that were obviously amenable to solutions from space.

The primary purpose of this part of the study was to stimulate ideas for further analysis. It is suggested that the reader not be overly concerned with the specific breakdown of the lists, the order of the items, or even the total completeness or wording of the individual items. If the items listed stimulate further ideas for opportunities in space then this exercise will have served its intended purpose. If not, no amount of restructuring or revision of the individual items or their groupings would be of any noteworthy consequence.

Table 1. Problem Solution Goals/Objectives - Population (Demographic, Social, Socio-Economic, and Communications/Mobility)

Time Frame		
Long	1.	Standardize languages/dialects
Short	2.	Improved education/job market synergism
Short	3.	Skill education (improvement)
Short	4.	Skill education (new job)
Medium	5.	Develop self-contained *packages* on specific subject matter and make universally available
Medium	6.	Develop system for disseminating information and education to remote villages
Long	7.	Record evolutionary development
Long	8.	Compile and document cultural identity
Long	9.	Compile and document ethnic identity
Short	10.	Entry of low skills into productive work
Medium	11.	Better utilization of female skills (no artificial barriers, better child care, etc.)
Short	12.	Better utilization of knowledge and skills even after retirement
Short	13.	Better utilization of handicapped
Short/Med.	14.	Optimum mix of do-it-yourself and special skills (labor costs and tax structure may be forcing too much bungling, time-consuming do-it-yourself)
Short	15.	Improved productivity of United States' workers
Short	16.	Productivity incentive (recognition, pay, promotion, etc.)

Legend:

Short - Needed and really should (or could) be done within the next 10 years.
Medium - Late 1980's or early 1990's.
Long - Near the turn of the century or beyond.

Medium	17.	Optimum work shifts
Medium	18.	Flexibility of assignments (assigning the right skill to a problem even if he lives in Chicago and the problem is in Pittsburgh)
Short	19.	Fewer interruptions and distractions for workers
Short	20.	Quieter environment for workers
Short	21.	Better access to existing data and designs (don't re-invent the wheel)
Short	22.	Improved public safety and law enforcement methods
Medium	23.	Schemes for keeping track of the disposition of criminals in our criminal justice system to assure swift and fair treatment
Short	24.	Methods for insuring that the country's recreational facilities are better utilized and less crowded
Short/Med.	25.	Safe, effective birth control methods which can be used by uneducated populations
Medium	26.	Develop stimuli for population control up/down
Short	27.	A morning-after pill
Short	28.	New communication techniques to disseminate information on the best available birth control techniques
Medium	29.	Less risky abortion techniques requiring little or no professional expertise
Long	30.	Schemes for selecting the sex of unborn children so that families don't have seven boys trying for a girl (or vice-versa)
Medium	31.	Provide periodic medical check-ups for world population
Medium	32.	Establish remote, automated diagnostic cent. s
Medium	33.	Establish disease warning network

Medium	34.	New techniques for the remote medical monitoring of the bodily functions of individuals who are recuperating from serious illnesses or suffering from chronic conditions
Medium	35.	Wider use of paramedics electronically linked to centrally located medical experts who can provide instantaneous medical supervision and advice
Medium	36.	Develop computer-aided medical treatment
Long	37.	Develop fluorocarbon blood substitute
Long	38.	Non-touching levitation for burn victims
Long	39.	Means of relieving body stresses (gravity) for health recovery
Long	40.	Completely safe environment for genetic and virus research
Long	41.	Search and identify new pathogenic bacteria and viruses
Long	42.	Develop vaccines for pathogenic virus (Lassa/Green Monkey Fever)
Short/Med.	43.	Develop rodent and disease vector population expansion detectors
Med./Long	44.	Develop rodent and disease vector control technology/systems
Medium	45.	Develop control for schistosomiasis
Long	46.	Assure participation in mankind's quests: • Exploration of space • Exploration of sea bottom
Long	47.	Identify new, efficient living areas • Climate • Energy sources • Food sources • Meaningful employment

Long	48.	Develop projections of socio-economic impacts of climatic changes
Medium	49.	Personal, portable communications systems which allow the user to be reached even if the caller doesn't know where he is located
Med./Long	50.	Transportation facilities which are more immune to the changes in the weather (e.g., freeways and airports)
Short	51.	Improved search and rescue methods for locating lost campers, downed airplanes, capsized boats, etc.
Med./Long	52.	Electronic shopping procedures
Medium	53.	New methods for the transfer of data in gagabit quantities from one computer installation to another by remote means
Short	54.	Rapid tamper-proof methods of credit verification and personal verification (cheap, sure and quick)
Long	55.	Electronic systems for the distribution of mail
Long	56.	Remote control techniques for dangerous or remotely located machines including those that are located in the space flight environment
Med./Long	57.	Elimination of the barriers of travel for all kinds of interpersonal (non-touching) relationships
Short/Long	58.	Less time spent in travel
Med./Long	59.	Teleconferencing methods to cut down on personal travel
Short/Med.	60.	Rapid and efficient office-to-office communications
Medium	61.	Methods to provide for the rapid access to stored records and library materials
Short	62.	Access to calculating power

Table 2. Problem Solution Goals/Objectives - Industrial Production (Including Materials and Water)

Time Frame		
Short	1.	Means for increasing worker productivity, particularly with respect to the other countries within the developed world
Short Med.	2.	Techniques such as cottage industries for putting unskilled laborers to work and to employ the large numbers of welfare recipients who are mothers with dependent children
Medium	3.	Ways for minimizing the possibilities for second and third generation welfare recipients
Medium	4.	Effective schemes for shipping jobs across international borders to help alleviate labor shortages and surpluses
Medium/Long	5.	Simple, inexpensive machines for Third World countries which will magnify the powers of the average semi-illiterate unskilled laborers
Short	6.	Means for tapping the potential of the marginal farm labor in many parts of the world
Short/Long	7	Faster methods of commuting to work
Short/Med.	8.	Method for being linked to the job electronically
Medium	9.	Improved machinery which is better adapted to the capabilities and limitations of unskilled human operators
Short/Med.	10.	Methods for reducing wasted materials, labor, and energy in large industrial operations
Med./Long	11.	Manufacturing processes which promote the easy adaptation to new product lines
Medium	12.	Methods for increasing the productivity in large distribution and sales operations (Red Ball Express?)

Legend:
Short - Needed and really should (or could) be done within the next 10 years.
Medium - Late 1980's or early 1990's.
Long - Near the turn of the century or beyond.

Short/Med.	13.	Contracting procedures whereby the loser of a large contract does not routinely end up with idle machinery and idle production capacity
Short/Med.	14.	Better means for insuring the protection of proprietary knowledge? (Make a big profit on a winner to balance out a lot of R&D on a bunch of losers.)
Short/Med.	15.	Identify optimal labor-intensive industrial options for underdeveloped countries
Long	16.	Develop water breathing technology/systems
Medium	17.	Smarter macnines (computer controlled, safetv features, less waste of material, fewer goofs, etc.)
Medium	18.	Structures which are more resistant to weathering and less affected by high winds
Med./Long	19.	Garbage disposal methods which make use of the potentially useful components contained within the gargabe and trash
Medium	21.	New methods of locating and assessing natural deposits of mineral resources, particularly fuels and scarce metals
Short/Med.	22.	Accurate inventories of the world's reserves of mineral resources
Short/Med.	23.	Substitutes for liquid and gaseous fuels which are equally easy to handle and transport
Med./Long	24.	Safer underground mining methods and less destructive strip mining techniques (See Energy-Coal Mining.)
Short/Med.	25.	Stockpiles of critical materials to avoid the pressures of monopolies and cartels
Medium	26.	Coal gasification and liquifaction methods which do not require large quantities of water (also land reclamation methods which are not water-intensive)

Medium	27.	More stable markets for the world's raw materials to cushion the shock of sudden price fluctuations on Third World nations
Long	28.	Wider use of renewable resources such as wood, sugar, and alcohol as a substitute for non-renewable resources
Med./Long	29.	Better methods or rust and corrosion control to increase the useful life of the world's materials
Med./Long	30.	Lighter weight planes and cars to achieve lower materials usage and reduced fuel consumption
Med./Long	31.	Means for the reduction of the loss of valuable property and precious materials from fires and other periodic disasters
Medium	32.	Reduced inventories of critical materials by better management of warehousing and transportation facilities
Med./Long	33.	More efficient design of buildings and other structures which use large quantities of materials
Med./Long	34.	New lubricants or other strategies designed to reduce frictional losses
Short/Med.	35.	Bigger, better semiconductor crystals
Medium	36.	New superconductors, particularly those which can operate at higher temperatures
Med./Long	37.	New methods designed to achieve the large-scale recycling of scarce materials such as mercury and silver
Short/Long	38.	Better pharmaceuticals
Long	39.	Develop mineral resources exploration techniques, e.g., ion ratios in water (petroleum), water leached minerals
Long	40.	Develop means for subterranean exploration for minerals

Med./Long	41.	Develop evaporation-retarding substances (surface and plant transpiration)
Long	42.	Identify areas of fossil water
Long	43.	Develop methods for mapping subterranean rivers
Long	44.	Identify potential river-reversal/diversion areas
Med./Long	45.	Develop means for killing/removing viruses in water
Med./Long	46.	Develop low-cost water purification processes (ozone)

Table 3. Problem Solution Goals/Objectives - Food

Time Frame		
Long	1.	More widespread use of the many potentially attractive foods which are now regarded as being undesirable or inedible (e.g. unusual vegetables, rough fish).
Short	2.	Effective methods of food distribution in disaster situations.
Medium	3.	Rice, wheat, and corn which contain larger concentrations of the essential nutrients.
Med./Long	4.	Synthetic meat products which have the desirable properties of real meat, but are much cheaper.
Short	5.	More encouragement of breast feeding in the underdeveloped world.
Short	6.	More widespread dissemination of clear information on proper nutrition.
Short/Med.	7.	Beverages which are both tasty and nutritious.
Med./Long	8.	Methods for making the low-nutrient soils of the jungles support crops without becomming bricklike. (Lateritic soils.)
Medium	9.	Economic methods for producing fertilizers on a small scale with simple equipment and mostly local materials.
Long	10.	Means for treating or crossbreading leafy crops such as hay or alfalfa so that they can be digested by human beings.
Short/Med.	11.	More widespread distribution of vitamins and food supplements, particularly for the world's pregnant women.

Legend:
Short - Needed and really should (or could) be done within the next 10 years.
Medium - Late 1980's or early 1990's.
Long - Near the turn of the century or beyond.

Long	12.	Schemes for producing edible foods in small houses and cramped apartments. (e.g., edible flowers.)
Long	13.	New strains of animals which produce more protein and less fat with less feed.
Short/Long	14.	Effective, inexpensive means of obesity control.
Short	15.	Foods or simple drugs which control intestinal parasites (Third World primarily).
Medium	16.	Market forecasts for food products about three years in advance.
Medium	17.	Weather prediction to precise geographical locations, precisely three days in advance and generally 10 to 30 days in advance.
Short/Med.	18.	Simple means for determining soil chemistry for the evaluation of fertilizer types and requirements.
Short/Med.	19.	Cheap sources of chemical fertilizers (by-products from other chemical processing operations?)
Short	20.	Control of water runoff to prevent soil erosion and to encourage soak-up.
Medium	21.	Methods for the detection and eradication of major crop pests and diseases.
Short/Med.	22.	More efficient methods of transporting crops to market, particularly in the underdeveloped world. (Like partial local processing.)
Short/Med.	23.	Means for reducing spoilage of crops on the ground (including accurate weather forecasting).

Long	24.	Irrigation methods which use readily available power sources such as wind and solar power.
Med./Long	25.	Abundant, reliable sources of water for irrigation purposes.
Medium	26.	Flavoring methods to make cheap, but nourshing foods taste good.
Long	27.	Substitute manufactured food for agriculturally grown food (e.g., food from petroleum, forestry waste products, or the like).
Long	28.	Weather control for major one-time devastating effects such as killing frost, tornadoes, hail, floods, etc. (Space laser?)
Long	29.	Well-planned fish farms on the open oceans and in protected bays and inlets.
Short	30.	Control of world-wide fishing to insure optimum catches and to avoid the overharvesting of certain types of acquatic creatures such as anchovies and grey whales.
Short/Med.	31.	Increases in the efficiency of meat and fish processing and storage operations.
Medium	32.	New incentives to help farmers achieve higher productivity, particularly in regions of the world where absentee landloards are prevalent. (Contests where fields are judged from space?)
Short	33.	Reliable sources of temporary, unskilled farm labor, particularly in the planting and harvest seasons.
Short/Med.	34.	Specialized herbicides which selectively kill weeds and other undesirable plants without harming useful crops, farm animals, or man.

Medium	35.	Pesticides which are not persistent in the soil and which do not enter into harmful synergistic relationships with other substances.
Medium	36.	Specialized insecticides which kill only the harmful pests, but which are harmless to innocent bystanders.
Med./Long	37.	Means for the major area control of harmful pests and weeds.
Med./Long	38.	Crop disease cures which can be quickly applied to the frontier of disease movements (implies accurate sensors to detect the frontier at any given time).
Short/Med.	39.	Methods for the practical education of farmers on major new farming methods and the availability of new farm machines and seed varieties.
Med./Long	40.	Reliable remote control units for gates, water distribution valves, etc.
Short/Med.	41.	Cheap, portable shelters for protection against winds and rains.
Short	42.	Distributed feeding to save fertilizer, but still keep animals warm, watered, etc.
Short/Med.	43.	Cheap remote sensors in cows to tell when they are sick or when they are in-heat.
Short/Med.	44.	Cheap and convenient artificial inseminators which can be used by unskilled farmers.
Long	45.	Sex control for artificial insemination sperm (or selective birth control pills or selective sperm vaccines).
Short/Med.	46.	More efficient cooking methods, particularly for Third World countries.
Short/Med.	47.	Develop foods (or processing methods) that require less cooking

Med./Long 48. Develop *low cost* energy sources for cooking:

- Solar
- Aeroelectrical Aeolian-electrical (cheap battery/charger)
- Methane

Long 49. Means for the reliable control of digestive efficiency for efficient obesity control.

Short/Med. 50. Better means of watershed management to protect crops and to insure the availability of water when it is needed for irrigation or power production.

Medium 51. Means for predicting several consecutive days of sunny weather for the harvesting of hay and other crops.

Med./Long 52. Methods for the control of off-shore fishing rights and the other rights of coastal nations.

Long 53. Develop protein extraction from inedible indigenous plants.

Long 54. Develop aquaculture and mariculture:

- Species of fish
- Fish food sources

$\Big\}$ Location, species, food

Med./Long 55. Locate essential fertilizer mineral deposits (P_2O_5).

Long 56. Develop palatable foods from insects.

Med./Long 57. Develop strains of poultry that are more efficient in tropics.

Med./Long 58. Develop calorie-variable junk foods (psychic satisfiers).

Long 59. Develop metabolism (temperature) elevating drug.

Medium	60.	Promote sugar substitute (as is done in Sweden)
Med./Long	61.	Develop food plants that can grow in salt/brackish water.
Long	62.	Explore merits of plant-animal hybrids for food.
Long	63.	Cash crops which are productive over a shorter growing season.
Short/Med.	64.	Methods for providing abundant nutritious food for the youngsters of the world during their formative years (brain food).

Table 4. Problem Solution Goals/Objectives - Energy

Time Frame		
Long	1.	Attractive substitutes for oil and natural gas.
Medium	2.	More energy-efficient machines and electrical devices.
Short	3.	Better insolation materials for homes and office buildings.
Short	4.	Thin-film coatings for windows which selectively pass some wave lengths while blocking others.
Short/Med.	5.	New methods for alleviating electrical peak loads.
Short/Med.	6.	Viable schemes for surviving energy embargos and resisting sudden unrealistic price increases.
Short	7.	Large high-quality crystals for the rectification of dc currents.
Long	8.	Terrestrial methods for energy *transmission* without wires (e.g., the terrestrial equivalent of microwave or laser transmission or converting to H_2, etc.)
Long	9.	High energy-density batteries for electric automobiles and other vehicles.
Med./Long	10.	Efficient energy storage methods for use in connection with our conventional energy grids.
Long	11.	Less energy-intensive procedures for producing aluminum, steel and glass.
Medium	12.	Turbine blades which are more resistent to high temperatures and stresses.

Legend:
Short - Needed and really should (or could) be done within the next 10 years.
Medium - Late 1980's or early 1990's.
Long - Near the turn of the century or beyond.

Long	13.	Schemes for the mass production of composite materials at a lower cost.
Long	14.	Extremely cheap solar collectors which are light, rugged and radiation resistant.
Med./Long	15.	Cheap, passive solar collector systems which will help reduce the nation's heating bills.
Med./Long	16.	More efficient methods for routing ships and airplanes to their destinations along fuel-saving routes.
Long	17.	Small, compact cities without internal highways in which most transportation is accomplished by walking and riding bicycles (but with still good quality-of-life).
Med./Long	18.	The personal equivalent of electric blankets which are worn on the body to provide direct heating.
Short	19.	Cheap, effective insulation materials which can be installed by the home handyman with a minimum of training and effort.
Short	20.	Cheap insulation using a minimum of energy and materials to produce.
Med./Long	21.	The recovery of processing heating from power generation facilities for reuse in secondary processes.
Med./Long	22.	Improvements in the utilization of process heat in connection with large-scale manufacturing processes (Europe is considerably more efficient than the United States).

Medium	23.	Increased operating efficiency for widely used machines such as auto engines, drill presses, electric motors and air conditioning compressors.
Med./Long	24.	Methods for transferring information such as credit cards and invoices which do not require the delivery of physical material.
Medium	25.	Cheap dual-pane windows or other efficient means for reducing heat losses through windows and doors.
Med./Long	26.	Attractive architectural alternatives to the use of large glass *curtain walls* in multi-story office buildings.
Long	27.	Substitute materials which are not as energy-intensive as the ones they replace.
Med./Long	28.	Small-scale, portable powerplants for the operation of fans, pumps, etc. (Solar or wind?)
Long	29.	Automated subsurface or strip mining techniques.
Medium	30.	Better techniques for converting coal into liquid and gaseous fuels.
Long	31.	New schemes for the location and exploitation of geothermal energy deposits.
Medium	32.	New ways to harness the power of the wind.
Med./Long	33.	New, more efficient methods for transporting gas, oil and coal to the point of need.
Long	34.	Breakthroughs in fusion technology

Long	35.	Intensive development of the technology leading to practical fast-breeder reactors.
Short	36.	Trustworthy schemes for safeguarding radioactive isotopes from theft, diversion, or inadvertant entry into the biosphere.
Medium	37.	Methods for locating attractive sites for new hydroelectric facilities
Long	38.	Accurate methods for monitoring the world's wind patterns on a continuous basis.
Med./Long	39.	Hybrid ships which utilize the wind on a routine basis, but which are also capable of self-propulsion to maintain schedules (under good conditions the sailing ships traveled faster than most of the commercial ships in use today).
Med./Long	40.	Sensors for the monitoring of major currents in the ocean and their temperatures.
Long	41.	New methods for the exploitation of tne energy locked within the world's oil, shale and tar sands deposits.
Long	42.	Automated tugs (unmanned) for towing icebergs using primarily wind power. (Remote control from space?)
Medium	43.	Identify areas for low-head turbine installation.
Medium	44.	Identify areas for water-mechanical power (hand-made).
Medium	45.	Identify areas for tidal power.
Medium	46.	Identify areas for solar power.
Medium	47.	Identify areas for low thermal differential delta turbines

Long 48. Develop non-gasoline motorcycle/automobile (electric-sun-wind-charged).

Long 49. Develop waste-powered electric plants municipal and plant.

Long 50. Develop efficient methane producer (bacteria strain).

Med./Long 51. Develop efficient absorption air conditioner (i.e., servel/LiBr).

Long 52. Identify optimal dam sites (energy and irrigation).

Long 53. Identify sea-sink power plant sites (Qattara).

Long 54. Develop low-cost night illumination techniques for crop tending/ harvesting.

Long 55. Develop integrated electrical energy systems

Table 5. Problem Solution Goals/Objectives - Political/Economic/Environmental (Includes National, International and Global)

Time Frame		
Short/Med.	1.	Methods to improve productivity of the country as a whole
Short	2.	Balance-of-payments improvements
Short	3.	Stable currency
Short	4.	Low unemployment
Short/Med.	5.	Effective procedures for minimizing painful oscillations in the nation's economy
Short/Med.	6.	Effective methods of policing international borders to prevent smuggling, unauthorized passage, and military intrusions
Short/Med.	7.	Remove threats to national sovereignty: from national/international crime; from narcotics; from terrorism
Short/Med.	8.	Automobile engines and stationary machines which are less polluting and less noisy
Med./Long	9.	More aesthetically pleasing methods for the distribution of electrical power to the user
Short/Med.	10.	A safe, effective means of disposing of nuclear waste products
Short/Med.	11.	Schemes for cleaning up oil spills on the high seas and along recreational beaches
Med./Long	12.	Quieter, more aesthetically pleasing transportation systems
Short/Med.	13.	Viable substitutes for asbestos and other man-made cancer-causing substances which are becoming so widely distributed in the biosphere

Legend:
Short - Needed and really should (or could) be done within the next 10 years.
Medium - Late 1980's or early 1990's.
Long - Near the turn of the century or beyond.

Short	14.	Effective methods for removing drunken drivers from public highways
Medium	15.	Substitutes for toxic substances, such as fluoride and carbolic acid, used in manufacturing processes.
Med./Long	16.	Means for insuring the higher combustion efficiency of hydrocarbons
Short/Med.	17.	New methods for safeguarding dangerous processes and dangerous materials
Short/Med.	18.	Means for preventing the spread of dangerous contaminants resulting from major catastrophies such as railroad accidents
Med./Long	19.	Means for the prevention of release of geothermal contaminants
Short/Med.	20.	Methods for the non-hazardous disposal of the waste products resulting from the extraction of coal, shale oil and tar sands.
Long	21.	Identify ill-defined borders
Short/Med.	22.	Workable methods for extending credit to Third World nations
Short/Med.	23.	Guarantees for investment capital for large-scale international ventures
Long	24.	Develop/implement zero-sum migration policies
Medium	25.	Assess optimal sources of natural wealth in under-developed countries
Long	26.	Develop local (national) mineral industries in under-developed countries
Med./Long	27.	Assure share of neutral resources to under-developed countries: • Fish - royalty for use of assigned grounds • Minerals - royalty for use of assigned grounds
Med./Long	28.	Assure *equitable* share of World Bank funds to each under-developed country
Med./Long	29.	Assure *equitable* contributions from developed country to World Bank

Medium	30.	Provide assured access to commercial over-flight rights
Medium	31.	Assured access to petroleum for transportation
Long	32.	Assure access to nuclear power/uranium resupply
Long	33.	Reverse trends towards pseudo nationalism in underdeveloped countries
Short/Med.	34.	Develop communication systems within under-developed countries
Short/Med.	35.	Allocate channels/frequencies to underdeveloped countries
Long	36.	International treaties which permit the technological exploitation of lunar materials
Medium	37.	International cooperation in the use of the geosynchronous altitude and other critical regions in space where the most desirable locations are intrinsically limited
Medium	38.	Effective control of the space debris fragments which are increasingly populating the space flight environment
Medium	39.	Workable international agreements on the use of spaceborne sensors and communication links
Med./Long	40.	Cooperative international procedures for the emergency rescue of endangered astronauts
Medium	41.	Means for insuring the security of major investments in space
Medium	42.	Treaties which insure the ability to keep and sell data obtained in space
Medium	43.	Encryption techniques for use in conjunction with direct broadcast and personal communications systems to insure privacy and security to the intended recipients
Med./Long	44.	World-wide cooperation in the construction and installation of an equatorial launch site
Medium	45.	Secure world-wide assignments of frequency bands for RF transmissions

Med./Long 46. Combustion processes which are less damaging to the biosphere

Short/Med. 47. Means for the short- and the long-term monitoring of nuclear fallout

Short/Med. 48. Monitor (detect) and control pollution:

- Water (domestic and across international borders)
  - Detect sources of sewage:
    - Chemical wastes
    - Thermal pollution
    - Eutrophication
    - Radioactivity
- Air (domestic and across international borders)
  - Detect sources of air-borne wastes:
    - Noxious
    - Toxic
    - Particulate

Med./Long 49. Monitor the effect of man's activities on the global weather patterns and the long-term climatic conditions

Long 50. Global monitoring of ocean currents and air circulation patterns

Med./Long 51. Long-term measurements of the earth's critical weather indicators (e.g., cloud cover, ice formation, mean temperature, etc.)

Med./Long 52. Correlation studies between the solar activity and the terrestrial weather and climatic conditions

Med./Long 53. Definitive studies of the effect of man's activities on the world weather and the world climate

Med./Long 54. Accurate methods for forecasting the world's long-term climate trends

Med./Long 55. Develop technology to monitor and control natural disasters (e.g., earthquakes, tsunamis, volcanic eruptions, tornados, hurricanes, etc.)

C. OPPORTUNITIES DESCRIPTIONS

APPENDIX C:

OPPORTUNITIES DESCRIPTIONS

1. DIRECT-BROADCAST EDUCATION - U.S.

1. GENERAL OBJECTIVE

Our present educational system utilizes audio-visuals to a limited extent and live television is available in some key school systems. However, televised instructional materials are not consistently available to the districts that need it the most despite the fact that it has been known for a long time that children learn readily from television programs, including those programs that are not intentionally instructive.

All basic school instruction attempts to convey information and elementary skills. Thus, one well-constructed curricula could be developed and presented to all children - if there were a way to ensure consistent delivery. Broadcasting from space to individual homes would make classroom activities more interesting and varied and would give the teacher interesting resource materials at the flick of a switch.

2. PRODUCT TO EARTH

High-quality universal elementary and secondary education based upon proven audio-visual (television) methods being developed by certain PBS and university activities. Initial phase would use local ground transmitters (UHF) and existing home receivers, broadcasting the existing classroom to these children unable (or unwilling) to travel long distances to schools. Local areas would be extended to rural regions via satellite, freeing the ground transmitters for extension to more specialized courses, such as accounting, business law (for small business entrepreneurs), automobile repair, computer programming, and special programs for the deaf. These broadcasts could be commercialized, similar to present extension college subjects.

Morning hours could be scheduled for primary education; afternoons, for cultural enrichment; evenings, to special-interest subjects. Adding a "talkback" capability would enable a desirable student-instructor and student-student interaction.

3. KEY OBJECTIVES

To provide a high-power multiple-channel UHF television relay to transmit to existing home receivers (direct broadcast); and to provide high-quality, efficient training to all students on a nondiscriminatory basis.

4. PRINCIPAL CONTRIBUTION

The delivery of interesting, varied, and high-quality material to our nation's schools. Among other things, this would free the teacher to provide more individual attention to his or her students without the necessity of working longer hours.

If desired, these broadcasts could be multilingual on a concurrent basis; thus, the child could listen once in English, then again in Spanish, French, German - with the serendipitous fallout of learning new languages painlessly. Since the curricula could be presented on multiple channels, with all phases in sequence, the student could advance at his own best rate. Programs could be recorded (no need for "live presentation") with instant replay of important points at the student's option.

5. LEVEL OF CONTRIBUTION

Delivered to home television receivers - each nation to prepare its own curricula, with controlled pattern of coverage. Extension to multinational or global service requires additional satellites, as a contracted service. Multiplication of television receivers to supply undeveloped and developing countries provides employment to large numbers; delivery of basic and technical training to these countries improves their productivity, generates customers for tools and conveniences from advanced developed countries.

6. UNIQUENESS OF CONTRIBUTION

The proposed system would help eliminate inequities and discrimination, and stimulate incentives for self-improvement. Satellite broadcast is the most feasible and least costly method of deliverying service to remote or widely dispersed areas.

7. TIME FACTOR

Initial phase, using ground transmitters, can be implemented immediately; extension to USA-satellite by 1990; extension to global area by 1995-2000.

8. PRINCIPAL INSTALLATION (Space only)

Geosynchronous high-power, low-frequency (UHF) multichannel transmitter; each nation provides central preparation facility for own language, own culture, broadcasts.

Number of beams per satellite	-	100 for the United States
Number of channels per beam	-	100
Bandwidth per channel	-	25 kHz to 6MHz
Power-gain product per channel	-	30 dB
Antenna size	-	Approximately 60 feet
Prime power	-	Approximately 150 kW
Orbit	-	Geosynchronous, equatorial

9. PRINCIPAL FUNCTIONAL UNITS

Low-cost television receivers identical to existing sets, with simple antenna (3-foot parabola) pointed towards zenith. Numerous course-preparation facilities (one per country). Commercial entrepreneurs prepare special-purpose courses, rent time on satellite (special unscrambler needed at receiver) sell to individual customers ($10 per course).

Talk-back requires adding small transmitter (audio) to user terminal, connected by wire to local center (urban and suburban)or by satellite to nearest center for rural areas. (One talk-back channel per broadcast channel.)

10. PRINCIPAL TECHNOLOGIES

Large (space) antennas for UHF (100- to 400-MHz transmission, plus necessary solar power assembly.

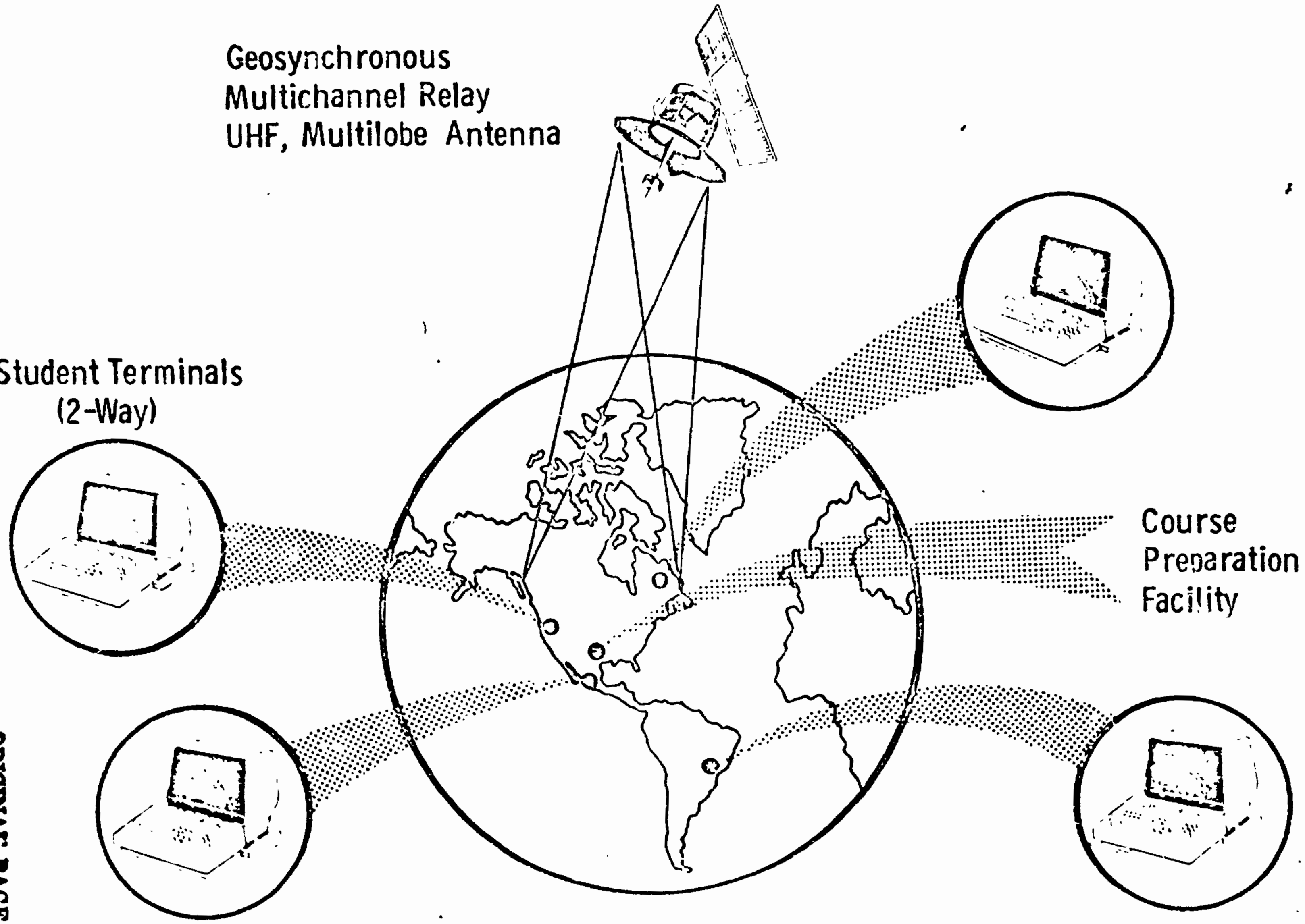
11. IMPACT SPECTRUM

Technology	-	Existing.
Economy	-	Improved trade with developing countries in global phase. Many jobs created to build ground system.
Environment	-	No impact.
Social	-	Great improvement in the quality of primary education.
Political	-	Improvement in international cooperation by interchange of subject material expands awareness of other nation's problems.
Scientific	-	No impact.

12. FRONT-END CAPITAL

About the same as one SBS satellite, plus ground terminals ($500M - estimate).

EDUCATION AT HOME



2. DIRECT BROADCAST EDUCATION - D ,ELOPING COUNTRIES

1. General Objective: Provide quality education in all areas of developing countries.
2. Product to Earth: Universal education based upon proven audio-visual (TV) methods. Children and adults.
3. Key Objectives: Decrease illiteracy, improve agriculture, sanitation, import knowledge necessary for more productive labor.
4. Principal Contributions: Accelerate development of 3rd and 4th world countries, improve quality of life, increase market for U.S. technology.
5. Level of Contributions: Benefits many times the cost of system. No credible alternative for many 4th world countries.
6. Uniqueness of Contribution: Relatively low cost, high quality and variety of education.
7. Time Factor: Near-term 1980 - 1990.
8. Principal Installations: Village ground stations; central (regional) computer with stored courses; education data relay satellite.
9. Principal Functional Units: Ground - classroom TV unit for transmitting course request, receiving and storing program, displaying program. Central computer. Course-generating team (arabic, french, english, etc.). Space - education data relay satellite in geosynchronous orbit. Weight 2000 lbs, size 14 ft x 15 ft, power 2000 watts.
10. Principal Technologies: Low cost high relability ground units, low cost power generating systems (i.e., wind mills, low-head turbines, etc.).

11. Impact Spectrum: Expanded market for television console units and educational courses.

12. Front-End Capital:

Acquisition Cost	
Ground units	$2,000 each
Computer/course data bank	$5 - 10 M
Software (initial)	$5 M
Satellite	$100 M
Transportation cost	$25 M
Annual Operating Cost	$1 - 5 M

3. BUSINESS SYSTEM DATA TRANSFER

1. General Objective: Interconnect commercial enterprises for communication/ transfer of business data.
2. Product to Earth: More efficient and timely interchange of commercial data.
3. Key Objective: Reduce cost of transfer of data and documents (facsimilies). Improve management decisions by making more current data available.
4. Principal Contributions: Increase corporate profits. Expand market for aerospace/electronic technology.
5. Level of Contribution: Benefits (commercial market potential) many times system cost. Analogous to savings over conventional, earth-based network of hard lines and microwave relay stations.
6. Uniqueness of Contribution: Low cost, speed of transfer of data and documents.
7. Time Factor: Near-term 1980-1990 (RCA SAT COM an operational fore-runner.)
8. Principal Installations: Transmitters/receivers at key facilities of all major industrial and commercial enterprises. U. S. initially - eventually world-wide. Data relay satellite(s) in geosynchronous orbit.
9. Principal Functional Units: Ground-company computer, word processors, and facsimile units all linked through a message-directly module to a roof-top antenna for transmitting to, and receiving data from Business System Data Transfer Satellite.
10. Principal Technologies: Message switching/directing system onboard satellite. Optimal antenna/power trade for satellite.
11. Impact Spectrum: Expanded market for electronic elements. Reduce U. S. Postal Service's First Class mail volume.
12. Front-End Capital: Acquisition Cost -

Ground Units (each - electronic interface only)	$ 5,000
Satellite	$300 M
Transportation Cost	$ 25 M

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4. ELECTRONIC TELECOMMUTING

1. GENERAL OBJECTIVE

Commuting by satellite.

About 20 percent of our present work force do office jobs at some central location. This type of work is handling records, thinking, writing - none of which requires attending a specific machine and could be done anywhere, since it is individual, not group, effort. Application of today's technology could, and soon will, implement an office-at-home.

2. PRODUCT TO EARTH

Conservation of resources (gasoline); improvement in office work productivity; reduced environmental pollution; reduced congestion in cities and freeways.

3. KEY OBJECTIVES

Using communications, intelligent terminals, and a CCTV approach, the usual office job can be accomplished by allocating one room at home to be an office. Even today, it is less costly to use a geosynchronous communications relay link than conventional landlines for long-distance telephone calls for distances as short at 600 miles. The charges, both nonrecurring and sustaining for implementing the office-at-home would be more than offset by the reduction in automobiles, gasoline, and highway maintenance if one-fifth of the population could work at home; a fringe benefit is a gain of one or two hours per day <u>not</u> spent in purposeless travel.

4. PRINCIPAL CONTRIBUTIONS

Application of this concept would: reduce our dependence on oil, gasoline; reduce urban pollution (smog) and congestion; eliminate 10 hours per week per person of nonproductive, irritating travel time (commuting);

eliminate large amounts of duplicated paper products (reports, slides, etc.)

5. LEVEL OF CONTRIBUTION

Every individual in urban and suburban areas would benefit: the white-collar workers by not commuting, the construction and manufacturing workers by easier access to roads, streets, parking; significantly cleaner air; easing of balance of payments (reduced gasoline consumption).

6. UNIQUENESS OF CONTRIBUTION

Very few office work activities require eyeball contact; where necessary, the CCTV provides an admirable, and even advantageous, alternative. It is easier to concentrate on one small screen than to try to watch a whole roomful of displays. Attention can be directed to the major points of emphasis; even hard copies can be transmitted, if meaningful.

And the worker is not limited to a home in the suburbs; it could be Bali - communication time is the same and just as clean and convenient. Office personnel, synchronized with the clock, can do their work when best adjusted; the relaxation in nervous tension alone would be worth the effort.

7.0 TIME FACTOR

Initial dispersion (United States Governmen services) by 1990; extend to United States commercial by 2000.

8.0 PRINCIPLE INSTALLATIONS

Space	One or more high-power communication relays.
Ground	Many small remote "intelligent" terminals and low-power transmitters. Preferably at EHF (10 to 900 GHz); several thousand audio-band channels for multiple random access.

9. PRINCIPLE FUNCTIONAL UNITS (SPACE ONLY)

The space element is useful only for long-distance communication. Regional linkages by fibre-optic cables similar to present telephones on CTV installations. Where needed, the space element would be analogous to the Satellite Business System Satellite. No new government-funded satellites are needed.

(Ground). Extension of CTV and/or telephone networks to individual terminals in small, neighborhood centers (10 to 100 workers); later to individual homes. Neighborhood centers include roof-top antennas for satellite linkages.

10. PRINCIPLE TECHNOLOGIES

All existing except high-power transmitter at k-band or higher.

11. IMPACT SPECTRUM

Technology	-	Very small requirement.
Economy	-	$ billions saved by eliminating 20 percent of automobile population, less gasoline, etc. $ millions added by increased productivity, relaxation of tension, etc.
Environment	-	Reduce pollution significantly· reduce centralized congestion; improve housing problem.
Social	-	Significant improvement in life style for many; should show immediate public acceptance.
Political	-	No immediate impact; long range may have effect of wide-scale decentralization.
Scientific	-	No impact.

12. FRONT-END CAPITAL

Space terminal about $50 M; ground terminals for $3 K each (10 million terminals).

5. WORLD MEDICAL ADVICE CENTERS

1. GENERAL OBJECTIVES

The majority of health care consists of out-patient treatment as opposed to hospital confinement. Out-patient treatment generally consists of data acquisition, analysis (diagnosis) and treatment of systemic disorders and/or treatment of trauma. The population per physician in the United States is approximately 650. In the 13 fourth-world countries, the population per physician ranges from 92,759 for Upper Volta down to 3700 for Sri Lanka, with a median of 27,700 (Indonesia)[1]. Furthermore, the average life expectancy of 20-year-old males in fourth-world countries such as India or Nigeria is on the order of 37 and 39 years, respectively. This means that the 20 years of food and education invested in half of the 20-year olds will be wasted because they will die before the end of their normally productive lifespan. The general objective is to provide improved health care to areas lacking physicians.

2. PRODUCT TO EARTH

Medical technicians at remote health clinics would take blood and urine samples and process them through automated clinical analyzers. The results of the analysis along with other data would be transmitted via satellite to a central, regional diagnostic computer that would process the data and send back the diagnosis and recommended treatment. The computer would also enter the case into files that would reveal incipient epidemics or "new" diseases, so that the appropriate measures could be initiated.

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[1] UN Statistical Yearbook 1972

3. KEY OBJECTIVES

The proposed system would enable third- and fourth-world countries to provide health care to improve the quality of life of their inhabitants and to protect their investments in food and education, thereby accelerating development.

4. PRINCIPAL CONTRIBUTIONS

An investment on the order of $20 M for a nation such as Mali could in a few years more than triple the current accessibility of health care. Training for a comparable number of physicians would require about 15 years. In tests held at medical conventions, computer diagnosis has been shown more accurate than conventional physician diagnosis.

5. LEVEL OF CONTRIBUTIONS

The training of physicians would require 12 to 16 years and cost approximately 30 percent more than the establishment of a medical clinic. New medical schools would need to be built, equipped, and staffed. Medical technicians to staff the clinics could be trained in about one year.

6. UNIQUENESS OF CONTRIBUTION

Low-cost, high-quality medical care could be extended to third- and fourth-world countries sooner and at a lower cost by this approach than by any other means.

7. TIME FACTOR

Near term 1980 - 1985.

8. PRINCIPAL INSTALLATION

Two-way terminals in "automated" medical clinics would be linked via satellite in geosynchronous orbit to a region's (continental?) medical diagnostic/treatment computer.

9. PRINCIPAL FUNCTIONAL UNITS

Ground:

Medical clinics equipped with automatic clinical analyzer[1], data transmission/receipt console, antenna, power source, and pharmaceutical stores.

Dianostic computer - one (shared by several nations).

Space:

Spacecraft for data relay between clinics and computer.

Constellation Size	- 1	
Orbit	- Geosynchronous	
Description	- Weight	- 3000 lbs
	- Power	- 2000 Watts
	- Size	- 15 foot diameter x 15 foot lens

10. PRINCIPAL TECHNOLOGIES

Spacecraft data relay to appropriate clinics.

11. IMPACT SPECTRUM

Technical - System is minor advance over existing technology.

Economic - Need to devise plan for financial structure of system(s). Improved productivity within developing nations. Preservation of investment of food and education to enable return on investment.

Environmental - Reduce likelihood of spread of untreatable diseases to developed countries.

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[1] Such as that produced by DuPont, Xerox Corporation, Union Carbide Corporation, or Technician Corporation

Social	-	Improved quality of life.
Political	-	Increased good will towards originators of system.
Scientific		Can detect potential epidemics early; detect presence of new diseases for medical study/ treatment development.

12. FRONT-END CAPITAL

Acquisition Cost:

. Medical Clinics:		
Clinical analyzers (2)	$ 0.04 M	
Console/Antenna/Gernerator	0.015	
Pharmaceutical Stores	0.020	
Building (Water, Sewage)	0.020	
Micellaneous Equipment	0.005	
Total		$ 0.100 M
. Diagnostic Computer:		2.0
Software		2.0
. Spacecraft:		
Development		100.0
Unit		25.0
. Launch Cost		25.0

Annual Operating Cost:

- Medical Clinic

  Personnel (4)

  Supplies

- Diagnostic Computer Center $ 1.0 M

6. TIME AND NAVIGATION SERVICES

1. GENERAL OBJECTIVE

Provide an accurate, universal time reference and a three-dimensional position determination capability.

2. PRODUCT TO EARTH

Time and location information.

3. KEY OBJECTIVES

Synchronize scientific reference clocks world-wide; enable mobile units to determine their location accurately.

4. PRINCIPAL CONTRIBUTIONS

Facilitate research into real time dependent physical and astronomical phenomena; enable precise navigation.

5. LEVEL OF CONTRIBUTIONS

GPS satellite network being implemented. Major benefits will stem from reducing size, weight complexity and cost of ground portion. Benefit potential many times anticipated cost.

6. UNIQUENESS OF CONTRIBUTION

Output as PIP on CRT/reference map format or via X-Y plotter on reference chart. Accurate, reliable, relatively inexpensive in large quantities.

7. TIME FACTOR

Near term 1980 - 1985.

8. PRINCIPAL INSTALLATIONS

Boats, ships, aircraft, cross-country vehicles for navigation; major scientic institutions/astronomical observatories for time reference.

9. PRINCIPAL FUNCTIONAL UNITS

Ground - standardized IC computer for basic location determination; output coupled to various display systems.

Space - GPS constellation.

10. PRINCIPAL TECHNOLOGIES

Reliable, low-cost, mass-produced ground units.

11. IMPACT SPECTRUM

Very widespread.

Military - Accurate weapon delivery.

Political - Reduction if inadertent territorial violations.

Societal - Ease of geographical position determination, thus, reduction of "lost" aircraft and boats.

12. FRONT-END CAPITAL

Minimal - GPS being implemented. Development of low-cost ground units: $1 M - $10 M. Unit cost: $100 - $200.

7. IMPLANTED SENSOR DATA COLLECTOR

1. GENERAL OBJECTIVE

To provide the service of receiving data from any earth source and returning appropriate information to the customer.

2. PRODUCT TO EARTH

Timely accurate, processed information. Examples are:

a. Read-out of water level sensors for control of dam gates

b. Emergency help to someone in distress

c. Sensors in cows to tell when they are in-heat for artificial insemination

d. Environmental data from remote or ocean locations

e. Fire warnings from heat or smoke sensors

f. Burgler or vandalism warnings from entry or noise sensors

g. Sensors throughout a huge strip-mining machine (operating on a winter night in Montana) sending up data to be processed on a large computer to warn of an impending failure

h. etc., etc., etc.

3. KEY OBJECTIVES

To open up a profitable service whereby we could use one satellite system and get paid by a multiplicity of users. It would also open up a wide variety of small businesses and jobs on earth as more and more ideas for products and services could be keyed to this capability.

4. PRINCIPAL CONTRIBUTIONS

The service of receiving almost any kind of data from anywhere within the covered region (like continental United States of America) and either relaying it on to its user and/or providing time share computer power to convert the data to information directly to the user.

5. LEVEL OF CONTRIBUTION

This depends on the economics of sharing the service across a large number of users. For each user, their function could be done with their own radio or wire links, their own computers, etc. However, if the space service were offered, there is a strong probability that ingenious uses would multiply rapidly. In such a case, this could become a multi-million dollar service function.

6. UNIQUENESS OF CONTRIBUTION

It is difficult to interconnect moving things with the bandwidth and all sorts of hills, buildings, etc., in the way. Hard wire is out of the question for things like combines, earth movers, etc. For stationary things, direct-wire to earth computers are difficult to compete with, particularly in cities. Outside cities, there may be economies in a space link, but you could nearly always put in a hard wire.

7. TIME FACTOR

Mid 1980's.

8. PRINCIPAL INSTALLATION

The space portion is basically a large antenna, perhaps including a large computer. The ground portion is a multiplicity of users, each with a small transmitter/antenna. (Does not need to be as small as a wrist radio/telephone.)

9. PRINCIPAL FUNCTIONAL UNITS

Antenna-like large structure in space, probably unmanned.

10. PRINCIPAL TECHNOLOGIES

Large structures, computers, coding/decoding to make maximum use of scarce bandwidth. Minimum cost ground transmitters.

11. IMPACT SPECTRUM

No significant impact.

12. FRONT-END CAPITAL (TBD)

8. NATIONAL INFORMATION SERVICES

1.0 GENERAL OBJECTIVE: National Information Services

The percentage of human time wasted in re-inventing wheels is incalculable; this is less due to ignorance of existing solutions than to lack of knowledge of where to find information about these solutions. All manner of ground information banks exist, and continue to proliferate. What is needed is a directory keyed to the user's problem description.

Such a directory could be implemented on the ground, using a geosync relay; however, each inquiry would then require four channels, two up and two down. If the directory were installed in the satellite, only one half-duplex channel per user is needed. To serve the public, several hundred channels would be required simultaneously. Each channel would have its own microprocessor to access one common mass memory. Updating, file maintenance, purging, etc., could be uplinked perhaps once a day.

2.0 PRODUCT TO EARTH:

Rapid access to sources of data relevent to all levels of technical, social, environmental and other concerns. Data banks exist at numerous governmental agencies, universities, and commercial operations that can be made available, for a nominal fee, to those individuals who are attempting to evaluate a problem situation and formulate an optimum, feasible solution.

3.0 KEY OBJECTIVE:

Provide a common, easily available directory similar to the Federal Information Center (Los Angeles); a telephone call will receive information on where to find the desired service, what agency, telephone numbers, mail addresses, application forms, etc. Expand this concept to include civilian and commercial data banks, and include sufficient automatic data processing for file search and retrieval (analogous to a library's card catalog or periodical indexes).

4.0 PRINCIPAL CONTRIBUTION:

Provides a single reference source wherein available knowledge can be readily accessed by any individual.

5.0 LEVEL OF CONTRIBUTION:

Usable by anyone with access to an "intelligent terminal" connected to local ground communications terminal.

6.0 UNIQUENESS OF CONTRIBUTION:

Combines in one address many data sources that exist, but are not generally known. Example: Few "users" of earth observation data are aware that there is a National E.O. data bank in South Dakota and that copies of LANDSAT-type data (false color photographs) can be obtained from there. The utilization potential of these data is enormous, but will not be realized until the concerned users (individual) know about it, and how to get it.

7.0 TIME FACTOR:

Ground-based central directory (programming) about five years; transfer to geosync facility by 1990; expansion to full commercialization by 2000.

8.0 PRINCIPAL INSTALLATION:

Centralized directory file preparation.

9.0 PRINCIPAL FUNCTIONAL UNITS:

Space, geosync automatic directory; ground, directory update facility.

10.0 PRINCIPAL TECHNOLOGY:

Information management; develop universal file search and retrieval syntax.

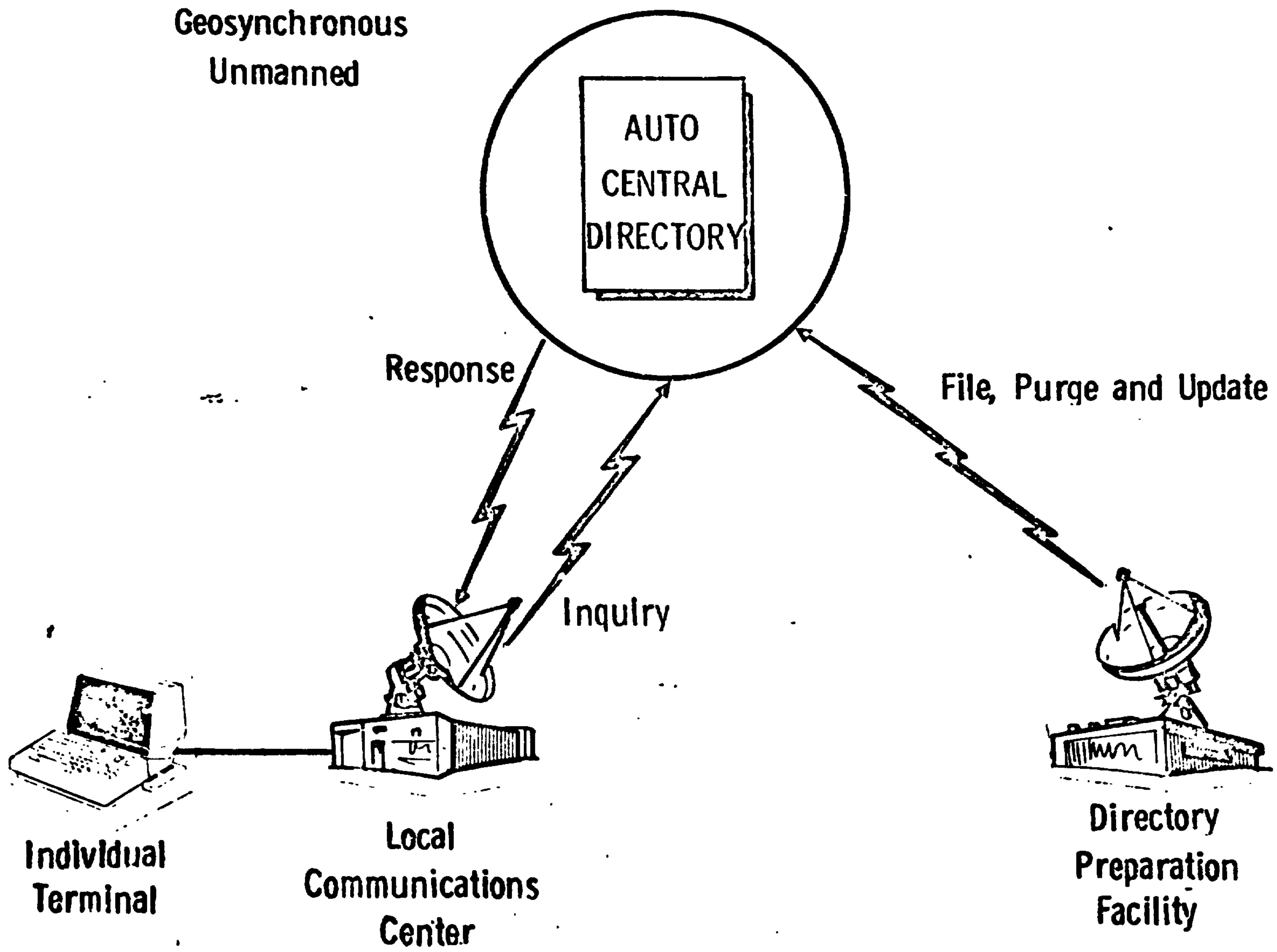
11.0 IMPACT SPECTRUM:

Technology:	Within present state-of-the-art.
Economy:	Increased productivity by avoiding redundant work. Potential commercial (not Government) operation utilizing DOMSAT-relay in initial stages. Employment of large numbers of personnel to collect, abstract and develop the directory.
Environment:	No impact.
Social:	No impact.
Political:	Would improve visibility of Government services, and relate use of public tax funds to individual benefits.

12.0 FRONT-END CAPITAL:

Directory data base, about \$500M; Geosync Directory, about twice that of a DOMSAT relay.

INFORMATION EXCHANGE



9. PERSONAL COMMUNICATIONS (WRIST RADIO)

1. General Objective: Provide personal communications capabilities to all interested Americans or at least a significant fraction of the general public.

2. Product to Earth: Communication capabilities of unprecidented power and flexibility.

3. Key Objectives: To allow any user to communicate with his colleagues on a nearly instantaneous basis even if their exact locations are unknown. Also to open up nationwide services such as library information to a broad segment of the general public.

4. Principal Contributions: Nearly instantaneous communications with friends and colleagues even under relatively adverse conditions.

5. Level of Contributions: Initial system would serve approximately 2.5 million users at an average usage rate of 5 percent. Later system could serve the entire American population, provided sufficient bandwidth can be obtained.

6. Uniqueness of Contribution: Terrestrial communication links could provide some of the envisioned services, however, it does not seem possible to install a nationwide system at a reasonable cost without satellite relay links.

7. Time Factor: Initial system could be available in the 1985 time frame. Full, nationwide system could be operational by 1990.

8. Principal Installations: Large array of multibeam antennas (approximately 200 feet in diameter) located in a geosynchronous orbit. Initial system would require 3 to 5 antennas; the nationwide system may require as many as 30 antennas of similar size. Raw power ≈ approximately 3 watts per user. This, in turn, necessitates a solar collector of approximately 65,000 ft^2 per antenna.

9. Principal Functional Units: Principal space units consist of one or more large, multibeam antennas which relay messages to various points within the continental United States. The antennas will likely be rigidly attached to facilitate mutual message exchanges. However, they could, instead, be electronically crosslinked.

10. Principal Technologies: The principal technologies necessary to make the system operate include complicated switching electronics, large multibeam antennas, accurage figure control methodology, and advanced thermal control techniques.

11. Impact Spectrum: Spectrum availability will constitute one of the major socio-economic problems associated with the personal communications system. The full-service system could require a bandwidth of 500 megahertz or more. Theoretically, this much of the spectrum could be used for the envisioned purposes, but this would require delicate international negotiations. Political conflicts with existing communications carries, such as AT&T, also seem likely to many observers.

12. Front-End Capital: To first prototype, $500 M.

10. ELECTRONIC MAIL SERVICE

1.0 GENERAL OBJECTIVE:

Analysis of the existing postal content indicates that the personal letter is one of the least components, and the bulk of what is in the mailbox are commercial notices, legal documents and advertisements. A significant component consists of magazine/newspapers. Dependence upon surface mail transport for documents is costly and somewhat less than dependable.

An extension of facsimile reproduction, if brought to the level of the individual home or office would fulfill the majority of the requirements although some security precautions would be needed to establish "true-copy" legality for some. However, mass mailing, subscription material (magazines, newspapers) could literally be delivered automatically and concurrently to every residence with one transmission.

2.0 PRODUCT TO EARTH:

Considerable savings in information distribution costs, manpower, fuel, increased productivity, user can select what to receive and copy.

3.0 KEY OBJECTIVES:

Establish meaningful transfer of information at high efficiency; positive transmission of documents by electronic, not material means, direct from sender to receiver; eliminate waste of costs and resources for unnecessary "shotgun" mail distribution, while assuring that receivers who want the material will receive it, and only that which they want. Extension to international mail is obvious.

Using cable television techniques, a number of mail collection/distribution centers would link the many recipients to the many senders via a high capacity satellite relay. The two terminal ends would be an "intelligent" facsimile device. Digital signal processing at the centers would combine the originators "mailing list" to the recipients "interest profile", thereby assuring that only those concerned in the document content are linked.

4.0 PRINCIPAL CONTRIBUTIONS:

Replacing physical transport of printed material by electronic methods may be the only way to rescue the USPS from its presently deteriorating state. Large quantities of paper (waste disposal), gasoline (aircraft, trucks) and under-utilized manpower are required to operate the existing system. Zip code, automatic sorting and regional centers are inadequate bandaids to cover up the nearly unsupportable task of distributing many billions of pieces of paper each year.

5.0 LEVEL OF CONTRIBUTION:

The Electronic Mail concept would link every individual to any other individual or selected groups of individuals. All the present USPS services (except parcel post) would be accommodated within hours, rather than days, in a non-polluting, material-resource-free form. Electronic forms replace nearly all printed information media.

6.0 UNIQUENESS OF CONTRIBUTION:

Electronic mail, in this concept, would provide more rapid, certain and secure delivery of information. No outside parties handle any communication; letters, bills, newspapers, etc., move from magnetic tape to magnetic tape (a re-useable media). The recipient reviews the message on a TV screen, and, if a file copy is desired, causes an output to a separate file tape on to a microfiche record (C.O.M.).

Billing statements and payments are also electronic; magazines and newspapers are scrambled so that only those who have paid for a subscription can receive it. Advertising (junk mail) is limited to those subscribers who have indicated an "interest profile". Private mail is address-coded so only the recipient with that code can read the message.

7.0 TIME FACTOR:

Complete linkage, within a given area, inside of five years: about the same time to install a cable TV system. Actual rate of expansion would be determined by the community's acceptance and willingness to subscribe to this service. Satellite linkage, point-to-point between the CTV centers could use existing DOMSAT or SBS systems. On-going experiment in Japan, using fibre-optic cable, will provide evaluation of feasibility, cost and customer acceptance.

8.0/9.0 PRINCIPAL INSTALLATIONS AND FUNCTIONAL UNITS:

Space:	One or more SBS satellites.
Ground:	1000 ground collection, switching and distribution centers (commercial) through which the USPS may lease one or more time-shared channels for first-class mail.
Ground, Subscriber:	Approx. 60 x 10^6 households, and 10 x 10^6 business operations would utilize "Intelligent Terminals".

10.0 PRINCIPAL TECHNOLOGIES:

Expanded channel relay satellites; automatic sort, switch and forward processors; minor expansion of computer terminal capabilities; development of fibre-optic cable systems.

11. IMPACT SPECTRUM

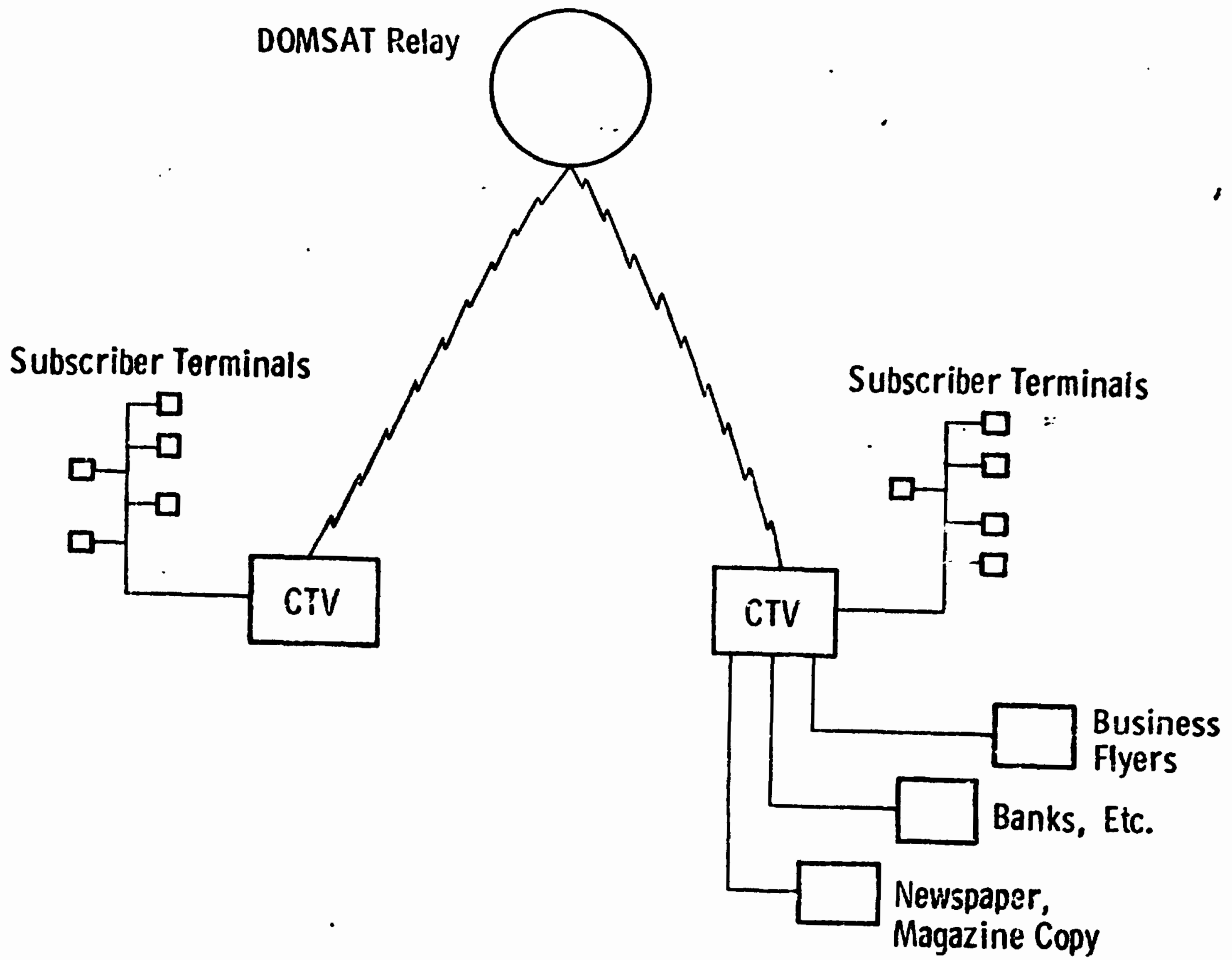
Technology	Within state of design.
Economy	Large number of jobs for CTV suppliers, installers, and operators; full USA-system would require no subsidy, perform more satisfactorily, and increase productivity for all nonmanual labor operations: a letter could be transmitted and a reply received within hours rather than days. Postal workers retrained as operators and maintenance. System could save at least $1.6 billion per year (present USPS subsidy), millions of man-hours, save fuel, relieve physical transport facilities, etc. Present USPS could concentrate on parcel post problem (16 billion packages per year).
Environment	Considerable reduction in paper production and disposal; large reduction in fuel requirements.
Social	Installation of "wired city" plus satellites for long-distance relay, with Intelligent Terminals in every home, would also provide the capability for "education at home," "commuting by satellite," "information exchange," and remote access to computer power, etc. Temporary dislocation of postal staff, producers of paper and printing presses lose markets, truck manufacturers and fuel suppliers would all be affected, temporarily.

Political	USPS monopoly on handling first class mail would be upset; AT&T, IBM, and digital processor manufacturers (like Collins) would react; paper suppliers, printing plants, and stamp collectors would be upset. Congressman (free franking privilege) would demand equivalent service. Except for protestations from unions and suppliers noted, no internal political impact is seen; international aspects would improve as communication (mail) is extended to other nations.
Scientific	No impact.

12. CAPITAL TO IOC

No governmental funds required; total system would be commercial. USPS retains monopoly on first-class mail by leasing channels. Equivalent to installing one pay TV net per post office; terminals, about as much as development cost of a minicomputer (have no clear data, but would be like $4 to $10 M. Production facility might require another $25 M. Retail price should be less than $500.

ELECTRONIC MAIL SERVICE



11. MEDICAL AID AND INFORMATION - U.S.

1.0 GENERAL OBJECTIVE:

To provide primary health care services to remote areas without access to hospital facilities or in-residence medical doctors. A recent survey indicates that over 100 counties in the USA have no resident physician.

2.0 PRODUCT TO EARTH:

A major part of primary diagnosis and treatment can be delivered by paramedic personnel on-site with advice and guidance from centrally-located experts. A maxim of medicine is that recovery is greatly enhanced by initiating treatment as early as possible to "stabilize" the patient; a complete diagnosis and recovery can then be made. By utilizing widely-distributed paramedics, or "physician assistants", health care can be brought to the victim rather than requiring the victim to come to a distant medical facility.

3.0 KEY OBJECTIVE:

Provide an accessible communication link (relay satellite) between widely-dispersed paramedical personnel and the limited number of profess[illegible]l medical specialists located in centralized hospitals. Provide training for many additional physician assistants for assignment to remote areas.

4.0 PRINCIPAL CONTRIBUTIONS:

Provision of primary medical observation and treatment to areas where none now exists. Present paramedic teams provide good service to densely populated urban/suburban areas; extension to thinly-populated areas is limited by transportation and communication obstacles. Availability of communications unlimited by wire or line-of-sight capabilities allows distribution of personnel to remote areas.

5.0 LEVEL OF CONTRIBUTION:

Direct delivery of help and treatment to the patient or victim. Present system requires delivery of patient to a distant treatment center; patients who are seriously ill, or accident victims, may not survive the transportation and delay.

6.0 UNIQUENESS OF CONTRIBUTION:

Improvement of the present system is possible if a communications link unrestricted by geography or surface facilities is provided. A satellite relay does overcome geographical limitations. EHF radio is limited by both line-of-sight and atmospheric attenuation, but is more than adequate to reach a synchronous satellite.

7.0 TIME FACTOR:

The space element could be in place by 1985; the dispersed paramedics could also be trained and in place by this time. Extension to other nations (using additional satellites) would be governed by the demand for similar capabilities.

8.0 PRINCIPAL INSTALLATION:

Space Relay Satellite with multi-lobe "spot-beam" antenna. Two-way linkage at high frequencies reduces size of antenna and total power needed.

Antenna Diameter:	15 feet
No. of Lobes:	100
No. of Channels/Lobe:	10
Bandwidth/Channel:	15 kHz
Power-gain/Channel:	30 db

Prime Power: 5 kW

Orbit: Synchronous, Equatorial

Ground: Paramedic ground transmitter must be light and battery-powered. Voice, narrow-band data capability is required. Base station is similar but multiplexed to serve several paramedics simultaneously.

Antenna Diameter	1 foot
Band Width	15 kHz
Power-gain/Channel	30 db
Prime Power	10 watts

9.0 PRINCIPAL FUNCTIONAL UNITS

Space: 1 to 10 satellites

Ground: 50,000 paramedics (one per 5000 population) tied to 100 regional hospitals (most already exist but need to add the emergency-response capability).

10.0 PRINCIPAL TECHNOLOGIES

RF system design, multi-lobe antenna development; ground terminal design.

11.0 IMPACT SPECTRUM

Technology: Existing

Economy: Employment for 50,000 paramedics, manufacturing jobs to build terminals, greater utilization of medical supplies.

Environment: No impact.

Social: Improvement in patient survival and rate of recovery; provide health service to large segments of population that have none at present.

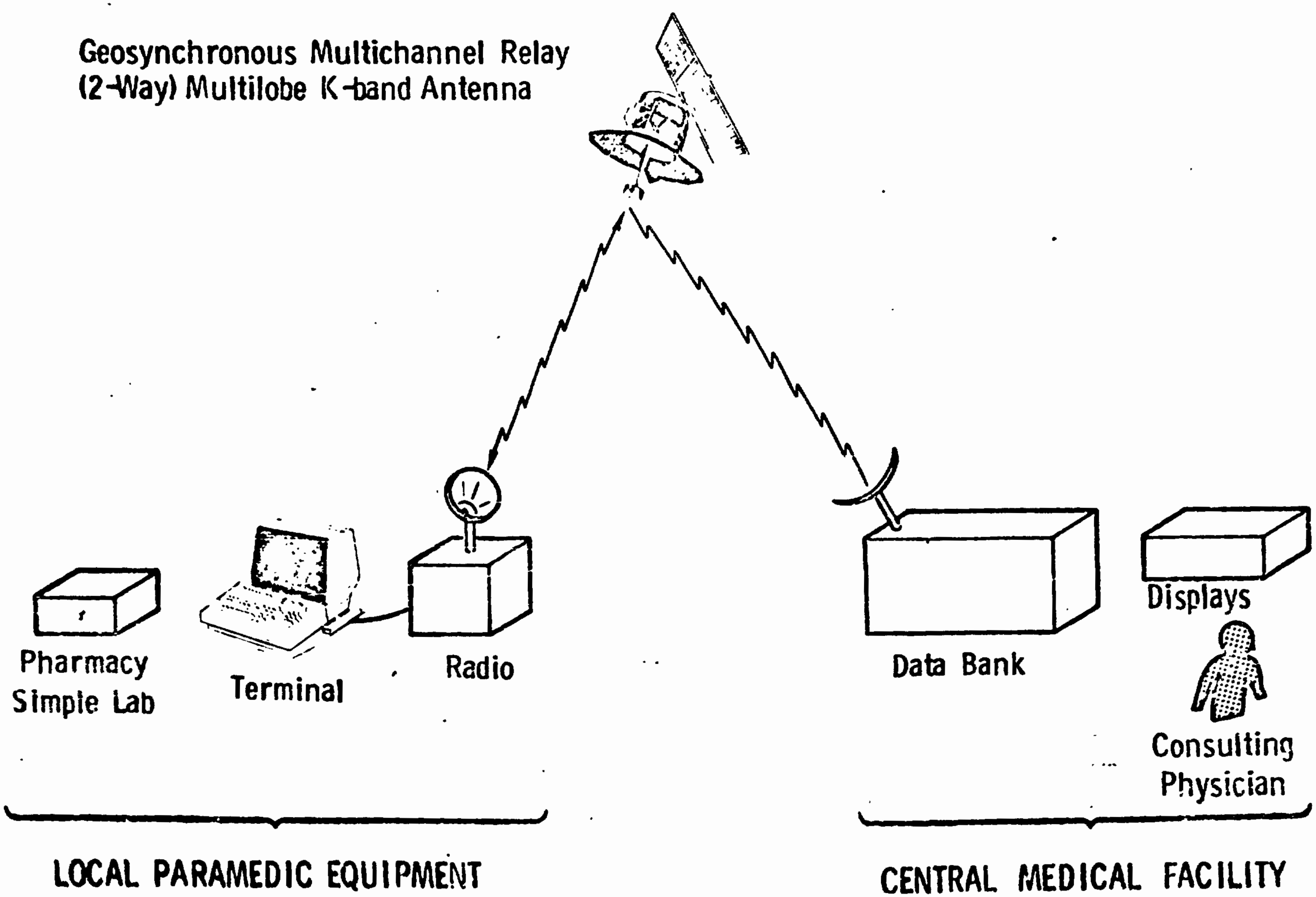
Political: Greater benefit to taxpayer than National Health Insurance; should be welcomed by A.M.A. to avoid nationalization of doctors' services. International (global) operations would enhance relationships with developing countries.

Scientific: Interchange of medical treatment methods between cultures would spread scientific knowledge rapidly.

12.0 CAPITAL TO L.O.C.

Space Element:	(one)	$500M
Paramedic Terminals:	(@ $10K)	$500M
Base Terminals:	(@ $50K)	$5M
Paramedic Training:	(@ $20K)	$1000M

PUBLIC HEALTH CARE DELIVERY



12. OIL/MINERAL LOCATION

1. GENERAL OBJECTIVE

As oil and other mineral resources become scarce, it is imperative that new techniques be found to increase our capability to locate these minerals. The proposed system would greatly enhance our capability to locate these ever-dwindling resources.

2. PRODUCT TO EARTH

Image negatives at a wide variety of wavelengths.

3. KEY OBJECTIVES

To provide multi-spectral analysis of the earth to determine the location of geologic formations, structures, and lineaments in order to locate possible reservoirs of oil, gas, as well as zones of mineralization.

4. PRINCIPAL CONTRIBUTIONS

This system will provide a quick, efficient, and less expensive means of locating resources.

5. LEVEL OF CONTRIBUTIONS

There is a definite need to increase land-surface coverage and the detail of this coverage in order to increase our mineral exploration capability. The needs can be met quite easily using a resource-evaluation satellite(s).

6. UNIQUENESS OF CONTRIBUTION

The trend in resource exploration is in a direction which will rely more and more heavily upon satellite reconnaissance. Satellite observation using photographs as well as multi-spectral scanners provides data which are of such quality that they can be obtained by no present alternative. However, the Thematic Mapper, to be launched in the mid-1980's, may be a viable alternative.

7. TIME FACTOR

The proposed system is required as soon as possible. Our nations ever-dwindling energy supply requires an increase in our capability to locate these resources.

8. PRINCIPAL INSTALLATIONS

The primary installations will be space-based monitors. Data acquisition will be from space-based observatories. However, earth-based sensors can be utilized in conjunction with the space-based monitors.

9. PRINCIPAL FUNCTIONAL UNITS

Space-based functional units may be manned or unmanned observation platform(s). The earth-based sensors may be useful in accumulating certain data which can then be transmitted via satellite to a central ground station.

10. PRINCIPAL TECHNOLOGIES

Technological advances are required to expand the capability to differentiate rock types, soil composition and geologic structures.

11. IMPACT SPECTRUM

The spin-offs of this system could be numerous. The detectability of a large variety of phenomenon could result from the technological advances required for this proposal.

This proposal could significantly enhance the U.S. energy reserve and will have a positive impact on environmental concerns.

12. FRONT-END CAPITAL

Satellite development and production	\$200M
Launch (0^o) VAFB	24M

Ground service	$ 10-50M
Transportation (Shuttle flights to retrieve film)	100M
Processing of data	50M

13. CROP MEASUREMENT

1. GENERAL OBJECTIVE

To evaluate the physical extent, maturity, and health of various crops.

2. PRODUCT TO EARTH

Photographic negatives and multispectral prints in a variety of frequencies to allow for crop analysis.

3. KEY OBJECTIVE

The proposed system will provide a quick, efficient, and accurate means of monitoring the stage of development of crops as well as the detection of crop diseases.

4. KEY OBJECTIVE

The proposed system will contribute significantly to man's ability to control, regulate, and monitor the development of crops.

5. LEVEL OF CONTRIBUTIONS

Millions of dollars are lost every year due to the late detection of disease and insect infestation, as well as the unexpected surplus of crops. The proposed system would greatly enhance man's capability to reduce these loses.

6. UNIQUENESS OF CONTRIBUTIONS

Outer space provides a unique opportunity to observe and analyze vast areas of crops using a variety of sensors. This capability is available on a limited basis from LANDSAT data. The Thematic Mapper, to be launched in the mid-1980's will increase these capabilities.

7. TIME FACTOR

This system should be implemented as soon as possible.

8. PRINCIPAL INSTALLATIONS

The principal installations would be space-based and consist of orbiting observatories that would transmit multispectral data. The photographic negatives would be retrieved by Shuttle flights.

9. PRINCIPAL FUNCTIONAL UNITS

No supporting units required. However, ground truthing will be required to enhance evaluation.

10. PRINCIPAL TECHNOLOGIES

Critical technologies will be required in the area of remote sensing in order to better differentiate crops and evaluate their maturity and health.

11. IMPACT SPECTRUM

Technologically and scientfically this system would require advancement of the state-of-the-art of remote sensing that would positively impact the area of mineral exploration.

Socially, politically, and economically the proposed system would have benefits. In general, it would allow better crop utilization and therefore maintain a more stable price system for agricultural goods.

12. FRONT-END CAPITAL

Satellite development and production	\$200 M
Launch (0°) VAFB	\$24 M
Ground Service	\$10 - \$50 M
Transportation (Shuttle flights to retrieve film)	\$100 M
Processing of data	\$50 M

14. OCEAN RESOURCES AND DYNAMICS

1. GENERAL OBJECTIVE

The world's oceans, comprising almost 70 percent of the surface, represent a vast source of food, minerals, and chemicals virtually untapped today, but essential in the future. Knowledge of fish feeding grounds, migratory habits, and ocean currents is sparse. Sensing ocean surface conditions (temperature, emissivity, and various wavebands from IR to visible) can locate schools of fish, plankton, and currents; trace migratory herds, etc. A near-earth space observation platform would provide this exploratory data.

2. PRODUCT TO EARTH

An increase in production of protein by location and (potential) management of sea life; knowledge of sea currents, both vertical upwells and horizontal movement; and identification of kelp and seaweed areas for harvesting.

3. KEY OBJECTIVES

Provide an observation platform to survey and map ocean areas, currents, and resource areas; improve world food production by identifying fish feeding areas and time of year when present; and establish resource management and conservation procedures to avoid overfishing certain species and areas.

4. PRINCIPLE CONTRIBUTION

Increased knowledge of this vast, largely unknown resource will permit greater (and better) exploitation for increasing human needs.

5. LEVEL OF CONTRIBUTION

Guidance to all sea-harvesting nations to the most productive local areas; present fish harvesting technology as "hunt until found," relying upon past experience (seldom shared) of individual fishermen.

6. UNIQUENESS OF CONTRIBUTION

Exploration and monitoring via satellite provides data in near real time (for fishing) and understanding of ocean dynamics and resources unobtainable by surface or air observation. One satellite could cover all ocean areas every 12 hours.

7. TIME FACTOR

Unmanned satellite could be in place by 1980; present SeaSat is prototype. Downlink data would require a synchronous data relay (such as TDRS) at the same time.

8. PRINCIPLE INSTALLATION

(Space only) - Satellite in 300-mile polar orbit with IR and multiband sensors; 24 to 30 MHz downlink data rate, 100-foot surface resolution, with .002 degree Centegrade sensitivity.

Weight	-	15,000 pounds
Size	-	10 x 60 feet (erected)
Raw power	-	25 kW

9. PRINCIPLE FUNCTIONAL UNITS

Space	-	One satellite, plus TDRS (2).
Ground	-	One control, tracking, and data handling center, linked by voice/facsimile to all major and minor fishing centers and fleets.

10. PRINCIPLE TECHNOLOGIES

. Multispectral data reduction, including unique "signature" analysis and identification.

. Long-term cryogenic cooling of long-wave IR sensors.

11. IMPACT SPECTRUM

. Technology	Extension of present development.
. Economy	Generate world-wide market for fish-location service.
. Social	By increasing availability of protein (fish) to developing nations, their living standards, health and productivity would be improved.
. Political	No impact nationally; international relations would improve.
. Scientific	Much increased knowledge of ocean dynamics would help understand the climatic aspects of the earth.
. Capital to IOC	Space only -- about $300 M.

15. WATER RESOURCE MAPPING

1. GENERAL OBJECTIVES

For third-and fourth-world countries that are seeking to expand their agricultural, as well as industrial, base, the availability of water is of paramount importance. Water quality, quantity, and seasonal variation all bear on developmental decisions. Synoptic mapping via ground or aerial surveys consumes scarce resources and can require years for completion.

2. PRODUCT TO EARTH

Photography from earth orbit at appropriate frequencies can provide the required data. The data can be in either film or video signal format. Large areas can be covered at satisfactory resolution.

3. KEY OBJECTIVES

Perusal of a sample of current development plans for third-and fourth-world countries reveals that the conduct of water resource surveys is an almost universal objective.

4. PRINCIPAL CONTRIBUTIONS

Water resource mapping from earth orbit would be more economical, faster (once the system is operative) than current mapping methods. Synoptic changes with the season could be readily obtained.

5. LEVEL OF CONTRIBUTION

Conventional aerial surveys cost $200 to $300 per square mile. If water resource mapping satellite costs $100 M, it would break even in mapping 400,000 square miles, or less than the land area of 6 of the 13 fourth-world countries.

6. UNIQUENESS OF CONTRIBUTION

Conventional aerial or land surveys provide data valid for the time (i.e., season) of the survey. Four-season coverage would quadruple cost. Four-season or repetitive coverage from earth orbit would incur only marginal costs. LANDSAT C and subsequent Thematic Mapper will contain required capability.

7. TIME FACTOR

Near term, 1980 - 1985.

8. PRINCIPAL INSTALLATION

One satellite in sun-synchronous polar orbit could cover the entire earth every 14 to 18 days, depending on altitude and view angle. Because of the possibility of cloud cover, several passes may be required to obtain data. Nationals could be trained to do photo interpretation and gather ground truth data.

9. PRINCIPAL FUNCTIONAL JUNITS

Spacecraft		Constellation size: 1
Weight	200 pounds	Orbit: Sun-synchronous
Power	1000 watts	
Size	10 ft. dia. x 15 ft. lens	

10. PRINCIPAL TECHNOLOGIES

Water-sensitive sensors with high resolution.

11. IMPACT SPECTRUM

- Technical - System is minor advance over existing technology. Applicable to other water-related missions (i.e., snow-pack measurement).
- Economic - Need to devise plan for financial reimbursement from user nations. Marked cost benefit advantage over current approaches.
- Environmental - No detrimental effects other than launch vehicle exhaust.
- Social - Conducive to accelerated rate of development of third- and fourth-world countries through more efficient development planning.
- Political - Possibly increased international good-will towards the United States.
- Scientific - Serendipitous discoveries likely.

12. FRONT-END CAPITAL

Acquisition Cost - \$80 M (LANDSAT evolution)

Launch Cost - \$24 M

Annual Operating Cost - \$10 M to \$100 M, depending on number of ground stations and data processing support required.

16. RUNOFF FORECASTING

1. General Objective

Snowpack melting is one of the primary causes of floods in the U.S. In the spring of 1973 35,000 persons were driven from their homes, and over 20,000 square miles were inundated by flooding in the Missouri-Mississippi River valleys. The damage incurred was estimated to be $____ M. The extent of flooding could have been reduced by better water management in the dams along the Missouri. (Fort Peck, Fort Randall, Garrison, Oahe, Tuttle Creek and Yellowtail). However, better management would require better knowledge of the snowpack and forecasting of the runoff. Snowpack measurement from space would provide essential data for improved water management.

2. Product to Earth

Snowpack measurement data and water level in tributaries of major rivers.

3. Key Objectives

A. Reduce flood damage by drawing down dams in anticipation of runoff.

B. Maximize water storage for irrigation and power generation within minimal damage criteria.

4. Principal Contributions

A. Reduced property damage, reduced crop losses, reduced loss of life.

B. More accurate and timely data than obtainable by surface surveys.

5. Level of Contribution

Aerial surveys cost $200 to $300 per square mile. Several 100,000 square mile area would need to be surveyed each year to manage the runoff on the Missouri-Mississippi River.

6. Uniqueness of Contribution

Snowpack measurement from orbit has been tested with LANDSAT data and proven feasible. Runoff forecasting and water management would require additional, unique temperature data and stream water level data.

7. Time Factor

Near Term: 1980 - 1985

8. Principal Installation

Two satellites in sun synchronous polar orbit could provide complete earth coverage every 7 to 9 days depending on sensor view angle and satellite altitude. Data would be relayed to ground stations where it would be computer processed and analyzed by computer comparison with topographic data. Results would be provided to appropriate government agencies.

9. Principal Functional Units

Constellation size: 2

Orbit: 500 NMi circular polar
Sun-synchronous

Spacecraft:

Weight	2000 lb
Power	1000 watts
Size	10 Ft Dia X 15 Ft Len.

10. Principal Technologies

Temperature sensors; water and snow sensors

11. Impact Spectrum

a. Technical: System is minor advance over existing technology

b. Economic: Flood damage reduction by half likely. Market service to foreign countries.

c. Environmental: Highly beneficial in alleviating potential flood damage

d. Social: Reduction of crop and pasture land losses, Improved irrigation and energy production by improved water management.

e. Political: Provide runoff forecasts to foreign nations. Provide disaster assessment of monsoon-flooded regions.

f. Scientific: Serendipitous discoveries of water sources likely.

12. Front End Capital

Acquisition Cost	$120M (LANDSAT evolution)
Launch Cost	$ 24M
Annual Operating Cost	$ 5M to $20M depending on extent of service provided.

17. GLOBAL EFFECTS MONITORING

1. General Objective: To develop an understanding ... leading to prediction and, perhaps, even modification/control of the long-term dynamics of earth surface, atmosphere, and magnetosphere, principally applying to weather, climate, and RF communications.

2. Product to Earth: Initially, science only. Eventually the ability to make accurate long-range forecasts of major weather/climate conditions on a global basis. Also, prediction of solar-activity-caused communications effects.

3. Key Objectives: The principal aspect of this initiative is the Solar Terrestrial Observatory whose mission is to investigate the coupling of the solar activity to the variability and dynamics of the earth's magnetosphere and atmosphere. Added to this (in this initiative) is:
   (a) if the sun/earth coupling does not explain it, what does? and,
   (b) a degree of predictability of the sun's processes that do affect earth.

4. Principal Contributions: The principal contributions are (a) longer-range weather forecasting, very long-range climate change prediction, possibly clues as to how to modify or control major weather/climate-caused natural catastrophies, and (b) more reliable RF communications.

5. Level of Contributions: Varies with time and global scope, but could become significant to the gross world product (i.e., possibly enormous impact).

6. Uniqueness of Contribution: Space is the only vantage point for unfiltered viewing of the sun and is a unique vantage point for observing/measuring earth phenomenon.

7. Time Factor: 1990's for major understanding (science) advancements. Modification/control well into the 21st Century.

8. <u>Principal Installations</u>: The STO is comprised of four basic space elements:

(1) A manned module attached to the low inclination, low-earth-orbit space station. This module will contain computers for processing and analyzing raw data required from the other spacecraft (via TDRS). Only processed data will be transmitted to the mission center on earth. Conceivably, tapes containing selected raw data could be transported to earth on return Shuttle flights. The module would be staffed by a crew of six.

(2) A module attached to the Public Service Platform in geosynchronous orbit to obtain data on solar variations on the surface of the sun, and to make direct particle measurements of the solar wind and its variability.

(3) A magnetospheric satellite in a high-inclination, low earth orbit to investigate the magnetospheric conditions that result from changes in the solar wind.

(4) A network of six solar wind satellites placed outside of the magnetosphere to obtain data on the temporal and spacial profile of the solar wind.

Ground installations will be basically the natural extrapolation of existing meaning and data processing functions, except that world-wide data is important to the understanding of varied regional effects.

9. <u>Principal Functional Units</u>: The space station module contains: optical instrumentation for studies of the sun and solar activity; optical instruments; lidar, and radiometry instruments for studies of the earth's atmosphere; and active instruments and particle measuring devices for studies

of the magnetosphere. It needs large enough crew to have the investigations occur around-the-clock. The smaller satellites are more like OAO or OSO size and complexity.

10. Principal Contributions: The new technologies are reasonable extrapolations of present state-of-the-art, particularly in lidar, laser radars and data processing of doppler effects, elastic scattering, electromagnetic spectrum and absorption signatures. Other system requirements for the space station module are:

Power	-	5 kW average; 20 kW peak
Pointing	-	arc seconds for optical instruments
Orientation	-	earth-pointing for atmospheric instruments; sun-pointing for solar instruments
Cooling	-	cryogenics for IR and other instruments
Data	-	1 Mbps peak (on-board recoding and analysis equipment required)
Telemetry	-	downlink-voice, real-time TV, periodic data transmittal uplink - same as above
Payload Weight	-	unpressurized - 10,000 kgm pressurized - 3,000 kgm
Crew Size	-	2 + 2 (12-hr shifts)

11. Impact Spectrum: Weather is a paramount driver in the daily lives of most of the people of the earth. Certainly many losses of crops, buildings, etc. could be saved with better short-range weather prediction. Long-range climate change prediction (if believed) could avert, or at least mitigate,

major multi-year catastrophes (to many). However, in such an interrelated system as global weather and climate, there will surely be legal and political implications.

12. Front-End Capital: Approximately $1.0 B.

18. LANDSAT D

1. General Objective: To establish feasibility and merits of high resolution multispectral scanning of earth.
2. Product to Earth: Synoptic earth data in seven spectral bands with twice the resolution of LANDSATS A, B or C.
3. Key Objectives: Detect surface features - both permanent and transitory that possess economic importance.
4. Principal Contributions: Demonstrate feasibility of acquiring high resolution earth data - which, when analyzed, provides economic benefits.
5. Level of Contributions: Based on LANDSAT A and B benefits, LANDSAT D should display benefits many times the cost.
6. Uniqueness of Contribution: Improved resolution and increased number of bands (over prior LANDSATS) present potential for earth resource detection that could exert major impact on food, mineral, and water resources and provide basic for improved management of spaceshy earth's resources.
7. Time Factor: Scheduled to be operational in 1981.
8. Principal Installations: Ground stations for receipt of data already in existence.
9. Principal Technologies: Thematic mapper contract awarded to Hughes in February 1977.
10. Principal Technologies: Sensors (thematic mapper) under development.
11. Impact Spectrum: Impact economics of all nations.
12. Front-End Capital: Funds authorized.

19. TOPOGRAPHIC MAPPING

1. General Objective

Borders of many third- and fourth-world countries are ill-defined. These need to be mutually established prior to intensive, detailed mineral resource mapping. The mapping should be of sufficient quality to enable 1:62,500 (1 mile to the inch) topographical mapping. Topographical maps are required for rational planning of roads, dams, irrigation canals, airfields, etc. To map fourth-world countries like Chad (495,000 square miles), Ethiopia (395,000 square miles), Mali (465,000 square miles), Niger (458,000 square miles), or Mauritania (398,000 square miles) by aerial photography, approximately 7000 photographs would be required of each if taken from an aircraft flying at 60,000 feet. In contrast, less than 150 satellite photographs would be required. As of August, 1976, the only complete coverage of the United States is at a scale of 1:250,000 (4 miles per inch), which is too small for many purposes. Computer processing would enable the automatic production of topographic maps from satellite data.

2. Product to Earth

Stereophoto data (60 percent overlap) at high resolution.

3. Key Objective

High-resolution earth mapping via satellite will enable the construction of detailed topographic maps necessary to national developmental planning. The topographic profiles will facilitate geological surveys in search of water supplies or mineral deposits.

4. Principal Contributions

Topographic data are essential to effective planning of transportation, water and energy systems. Because of the long time and high cost required to gather such data by conventional means, developmental decisions in the above areas will be made on fragmentary or erroneous data. Generation of topographic data by satellites can provide this data economically and quickly, and because of the wide area covered by each frame, ground processing of the data is reduced.

5. Level of Contributions

Conventional aerial surveys cost on the order of $200 to $300 per square mile. By spreading the cost of the satellite system over the many potential users, the cost of obtaining the needed data should be reduced by an order of magnitude. Computerized processing of the data could make the desired maps readily available.

6. Uniqueness of Contribution

No current space system can provide the required data.

7. Time Factor

Near term, 1980 - 1990.

8. Principal Installations

A satellite in a high inclination or sun-synchronous orbit would be required. Depending on technological advances, either high-resolution film - to be recovered by the Shuttle - or a high-resolution video system with either a very large data storage and high-speed dump capacity (or possibly data relay via satellite) would be required. Because of the specialized nature of the computer processing and personnel skills required, one facility is envisioned.

C-2

9. Principal Function Units

Constellation size: 1	Spacecraft:
Orbit: Sun-synchronous	Weight 3000 lbs
	Power 2000 watts
	Size 14 ft dia. x 20 ft len.
	Payload: Self-loading camera and film reels or video scanner with data storage.

10. Principal Technologies

High-resolution video, large capacity data storage or replaceable film storage and protection module with automatic film loading. The video approach is preferred because it would eliminate the need for periodic Shuttle support missions.

11. Impact Spectrum

Technical	-	System is largely an application of military technology with modest improvements over correct S-O-T-A.
Economic	-	Plan for amortizing cost would need to be developed.
Environmental	-	No detrimental effects other than launch vehicle exhaust.
Social	-	Conducive to more efficient development of third- and fourth-world countries through improved development planning.

Political	-	Possible need to establish international consortium to acquire and process nationally sensitive data.
Scientific	-	Serendipitous applications to geology, mineral, and water surveys.

12. Front-End Capital

	Video	Film
Acquisition cost	\$150 M	\$80 M
Launch cost	24	24
Annual	10 - 50	105 - 150 (service 90 days)

20. HIGH-RESOLUTION RESOURCE SURVEY

1. GENERAL OBJECTIVE

To determine the best application of various sections of land from the point of view of agriculture, energy, recreation, and social needs.

2. PRODUCT TO EARTH

Photographic and/or multispectral scans indicating soil, rock type, water table depth and boundaries, snow cover and other pertinent information that might affect land use.

3. KEY OBJECTIVES

The proposed system would provide a quick, efficient, and accurate means of performing land mapping and land inventory.

4. PRINCIPAL CONTRIBUTIONS

There is an ever increasing necessity to utilize land to its best capacity. The proposed system would allow efficient, arge-scale, as well as detailed, evaluation.

5. LEVEL OF CONTRIBUTIONS

Many thousands of acres of land are unused or are used inefficiently. The proposed system would greatly reduce this waste of natural resource.

6. UNIQUENESS OF CONTRIBUTION

Outer space provides a unique opportunity to observe and analyze vast areas of land using a variety of sensors. This capability is not available at present and would be especially useful to underdeveloped countries of the world. The best alternative to the proposed system is the Thematic Mapper to be launched in the mid-1980's.

7. TIME FACTOR

This system should be implemented as soon as possible; the space hardware is relatively small and compact.

8. PRINCIPAL INSTALLATIONS

The principal installations would be space-based and consist of orbiting platforms that would transmit multispectral data. The photographic negatives would be retrieved by the Space Shuttle.

9. PRINCIPAL FUNCTIONAL UNITS

No supporting units required, although some ground truthing may be necessary.

10. PRINCIPAL TECHNOLOGIES

Critical technologies will be required in the area of remote sensing in order to better differentiate soil types, moisture, vegetation, and other pertinent characteristics.

11. IMPACT SPECTRUM

Technologically and scientifically this system would require advancement of the state-of-the-art of remote sensing that would positively impact the area of mineral exploration and crop management.

Socially, politically and economically the proposed system would have substantial benefits. In general, it would allow better land utilization and provide for long-range planning as a result of an accurate land capability.

12. FRONT-END CAPITAL

Satellite development and production	$200 M
Launch (0°) VAFB	24 M
Ground service	10 - 50 M
Transportation (Shuttle flights to retrieve film)	100 M
Processing of data	50 M

21. HIGH-RESOLTUION RADAR MAPPER

1. GENERAL OBJECTIVE

Provide surface resource and mapping data for cloud-covered regions.

2. PRODUCT TO EARTH

Synoptic data on mineral resources, crops, rivers, and other geographic characteristics for areas where cloud cover precludes acquisition of data via conventional satellites or aircraft.

3. KEY OBJECTIVES

Provide developing nations with internal data essential for their national development.

4. PRINCIPAL CONTRIBUTIONS

Facilitate mapping of inaccessible regions of developing countries where perpetual vegetation generated smog, haze, fog, or clouds prevent direct observation. Determine extent of flooding under cloud cover.

5. LEVEL OF CONTRIBUTION

Need additional data on extent of cloud-covered regions and probability of observation by conventional satellite.

6. UNIQUENESS OF CONTRIBUTION

Competition from radar equipped mapping aircraft needs to be examined further (side-looking radar, sythetic aperture).

7. TIME FACTOR

1985 - 1990

8. PRINCIPAL INSTALLATIONS

Because of need for low altitude to improve resolution, coupled with data storage limitations, ground stations (mobile) need to be provided in areas to be mapped. TDRS to central receiving station is an alternative.

9. PRINCIPAL FUNCTIONAL UNITS

Ground - Mobile data receiving stations equipped with internal power generating units and data processing facilities. TDRS relay of data to central ground station is an option.

Space - High-powered, radar equipped satellite (1 to 3 gigahertz frequency) in relatively low polar orbit.

10. PRINCIPAL TECHNOLOGIES

Satellite - particularly radar antenna and related electronics.

11. IMPACT SPECTRUM

Depends on (a) extent of perpetually cloud-covered areas; (b) need for repetitive (e.g., seasonal) coverage; and (c) economics of radar coverage from high-flying, synthetic aperture radar-equipped aircraft.

12. FRONT-END CAPITAL

Satellite cost estimated at $500 M

22. ISOENZYMES

1.	General Objective:	Manufacturing of Isoenzyme Diagnostic Kits for early/effective diagnosis of disease.
2.	Product to Earth:	Extremely high efficiency diagnostic kits for medical doctors to diagnose patients. Should be much more effective in early detection/warning of contagious or catastrophic diseases.
3.	Key Objectives:	To provide more effective ways of combating vectors of disease/save lives.
4.	Principal Contribution:	Unique bio-chemistry enabling medical science to improve its efficiency in diagnosing/curing patients.
5.	Level of Contribution:	Each doctor in the field or in city hospitals will have access to these inexpensive kits.
6.	Uniqueness of Contribution:	No way to produce such a product on earth. Its amplification of effectiveness must be determined empirically.
7.	Time Factor:	Early 1980's.
8.	Principal Installation:	Near-Earth-Orbit Manufacturing Facility: (1) free flyer, (2) space station, or (3) spacelab.
9.	Principal Functional Units:	Isoenzyme (anti-body-type) vaccine to be injected in patient.
10.	Principal Technologies:	Separation of proteins (enzymes) via electrophoresis.
11.	Impact Spectrum:	To be determined.
12.	Front-End Capital:	To be determined (will be combined with many other items)

23. UROKINASE

1. GENERAL CLASSIFICATION:

Space manufacturing of small, high-value/low-mass products.

2. GENERAL OBJECTIVE:

Manufacturing of large quantities ($\sim$ 10 kg/yr) of the organic catalyst enzyme-'urokinase', for medical and pharmaceutical industries.

3. PRACTICAL APPLICATION:

Save lives. Dissolves blood clots after they have formed.

4. SUBSTANTIATION OF IMPORTANT NEEDS:

- Key Objective: To cure victims of strokes, hardening of the arteries ... by producing a product that will disolve blood clots after they have formed.
- Principal Contribution: Will provide medicine with a unique product to combat 'blood clot' related diseases.
- Level of Contribution: Production of large amounts of 'urokinase' will benefit victims of heart attacks, strokes, phlebitis ...7 to 100 times more of the product will be possible in orbit.
- Time Factor: 1981 - 1982.
- Principal Installation: N.E.O. manufacturing facility. (1) Free Flyer, (2) Space Station, or (3) Spacelab.
- Principal Functional Units: Electrophoretic separators.
- Principal Technology: Electrophoresis separation of cells.

5. IMPACT SPECTRUM:

- Technology: Existing/improvement in instrumentation needed.

- Economy: Pharmaceutical industry will benefit financially. Perhaps one percent of U.S. population will benefit. The economic effects of a healthy work force is difficult to quantize, but could not help but improve the economic condition of the country.
- Social: Product to earth will save more lives, create a healthier society.
- Political: A large (surplus) supply of this product would certainly be in demand worldwide Would help U.S. balance-of-trade (payments).
- Scientific: Medical breakthrough.

6. FRONT-END CAPITAL:

- STS Cost: $25 $1000/# ?
- DDT&E Costs: TBD
- ROI: TBD

24. INSULIN

1. General Objective: Supply insulin treatment to one million persons per year at lower cost to avoid the "insulin crisis" in which demand is projected to exceed supply.

2. Product to Earth: Cured insulin of human or non-human source and/or tissue culture of insulin producing cell.

3. Key Objectives: Make available a cheaper and safer source of insulin to overcome the limitation on insulin sources.

4. Principal Contributions: Low cost human insulin produced from cultures of pancreatic cells.

5. Level of Contribution: Over 30,000 people die of diabetes each year, and over one million require daily doseages. This rate is increasing and appears to be unchecked.

6. Uniqueness of Contribution: Terrestrial production is limited in supply efficiency and no human insulin is available except for research applications. Zero-g environment seems to hold promise for overcoming these limitations. Insulin synthesis is an alternative and not practicable for production.

7. Time Factor: Since insulin has FDA approval, near-term availability depends mainly on the results of proving of the process. Human insulin production by 1985 may be achieveable.

8. Principal Installations: Low earth orbit manufacturing facility: (1) free flyer, (2) Space Station, or (3) Spacelab.

9. Principal Functional Units: Electrophoretic-separators.

10. <u>Technology</u>: Recrystallization and gel filtration the present method of insulation purification. The use of electrophoresis in space may improve the efficiency of the process. Production from pancreatic cell cultures in space may provide the more desired source of human insulin.

11. **Monitor research** leading towards production of insulin by genetic modification of E-Coli.

11. <u>Impact Spectrum</u>: Development of entirely new process for production of insulin. Save thousands of lives by expanding supply to satisfy the foreseen demand.

12. <u>Front-End Capital</u>: Space facility estimated at $100 M. (Assumes legacy from on-going and precursor programs).

25. SUPER LARGE SCALE INTEGRATED CIRCUITS

1. GENERAL CLASSIFICATION

Space manufacturing of small products

2. GENERAL OBJECTIVE

Manufacture of defect free substrate wafers for LSIC chips and computer storage applications.

3. PRODUCT TO EARTH

Large scale integrated circuit chips (LSIC). Bubble memory devices.

4. KEY OBJECTIVES

To provide the micro-electronic industry with ultra high-resolution photolithography for imprinting circuits with line spacings measuring in the millionths of an inch. Seismic motions of the earth inhibit such small separations of circuit lines.

5. PRINCIPAL CONTRIBUTION

Use the vibration-free environment of space to perform such operations. Will benefit the micro-electronic industry.

6. LEVEL OF CONTRIBUTION

Annual market assessment of the communications products such as ATC radar, collision avoidance systems for aircraft alone are estimated at 100 $\overline{M}$/yr.

7. UNIQUENESS OF CONTRIBUTION

Benefit communication needs (military and civilian) improves yield factor. Produce LSIC with $\lambda/4 \rightarrow \lambda/2$ spacing for high frequency applications. Only way to isolate process from terrestrial and eusmic and acoustic coupling vibrations.

8. TIME FACTOR

1985 to 1990

9. PRINCIPAL INSTALLATION

NEO manufacturing facility.

10. PRINCIPAL FUNCTIONAL UNITS (TBD)

11. PRINCIPAL TECHNOLOGIES

- Crystal growth from a melt
- LSIC photolithography techniques

12. IMPACT SPECTRUM (TBD)

13. FRONT-END CAPITAL (TBD)

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26. SILICON WAFERS FOR DC RECTIFIERS

1. GENERAL CLASSIFICATION

Space manufacturing of high value/low mass products

2. GENERAL OBJECTIVE

Manufacturing of flawless silicon wafers for large scale electrical power rectification

3. PRODUCT TO EARTH

Silicon control rectifiers for public utilities companies

4. KEY OBJECTIVES

To provide: power equipment builders with large (15 cm diameter) and dislocation-free silicon semiconductor components for control rectifier devices used in ac/dc/ac power converter facility stations

5. PRINCIPAL CONTRIBUTIONS

For this specific application of single crystal silicon, there is an urgent need for flawless, large diameter (~15 cm) wafers for use in ac/dc/ac power conversion system, i.e. conversion rectifiers.

6. LEVEL OF CONTRIBUTION

Will provide the power industry with semiconductor rectifier silicon wafers (10-15 cm) that can handle up to 700 amperes and reduce the amount of smaller size (SCR's) ... to handle up to 360 megawatts of power.

7. UNIQUENESS OF CONTRIBUTION

The float zone refining method is capable of producing high grade wafers (~ 4 - 5 cm) diameter SCR's... for electrical power applications. However, the primary impediments are large diameter wafers. Space manufacturing can provide this unique semiconductor material.

8. TIME FACTOR

~ 1985

9. PRINCIPAL INSTALLATION

NEO manufacturing facility, i.e., free flyer, space station, spacelab.

10. IMPACT SPECTRUM (TBD)

11. PRINCIPAL TECHNOLOGY

- o Crystal growth from a melt/zone refining

12. FRONT-END CAPITAL (TBD)

27. NEW OPTICAL GLASS

1. GENERAL CLASSIFICATION

Space manufacturing of small products

2. GENERAL OBJECTIVE

Manufacturing of optical glasses for refractive optics and laser windows.

3. PRODUCT TO EARTH

New glasses with superior characteristics: IR transparency, high strength, pure, thermal shock resistant glass.

4. KEY OBJECTIVES

To obtain containerless melt to minimize: convection and contamination and sources of nucleation to prevent devitrification.

5. PRINCIPAL CONTRIBUTION

High index/ABBE number glasses. 5-10 μ IR transparency improvement for lasers.

6. LEVEL OF CONTRIBUTION

Optical instruments and lens market estimation 10 $\overline{M}$/yr.

7. UNIQUENESS OF CONTRIBUTION

No way to dc containerless melts in terrestrial industries; therefore, space only way to go.

8. TIME FACTOR

~ 1985 - 1990

9. PRINCIPAL INSTALLATION

NEO manufacturing facility.

10. PRINCIPAL FUNCTIONAL UNITS

Furnace melt facility

11. PRINCIPAL TECHNOLOGY

Existing glass manufacturing

12. IMPACT SPECTRUM (TBD)

13. FRONT-END CAPITAL (TBD)

28. FIBER OPTICS

1. GENERAL CLASSIFICATION

   Manufacture of small products in space

2. GENERAL OBJECTIVE

   To produce high transmission fiber-optics in space.

3. PRODUCT TO EARTH

   Fiber optics for applications in optics, e.g. communication by wideband light beams.

4. KEY OBJECTIVE

   To obtain containerless melt to minimize convection and contamination and sources of nucleation to prevent devitrification.

5. PRINCIPAL CONTRIBUTION

   Very high transmission fiber optics with a minimum of losses.

6. LEVEL OF CONTRIBUTION

   Medical, communication industry will benefit.

7. UNIQUENESS OF CONTRIBUTION

   No way to do containerless melting in 1-G terrestrial environment - space unique in that industrial sense.

8. TIME FACTOR

   ~ 1975 - 1990

9. PRINCIPAL INSTALLATION

   NEO manufacturing facility.

10. PRINCIPAL FUNCTIONAL UNITS

    Furnacemelt facility fiber drawing apparatus.

11. PRINCIPAL TECHNOLOGY

    Existing.

12. IMPACT SPECTRUM (TBD)

13. FRONT-END CAPITAL (TBD)

29. HIGH-TEMPERATURE TURBINE BLADES

1. GENERAL CLASSIFICATION

Space manufacturing of small products

2. GENERAL OBJECTIVE

Manufacture of high temperature/high strength metal turbine blades for turbojet and power conversion-type engines.

3. PRODUCT TO EARTH

Long life/high temperature turbine blades for fuel burning turbojet engines.

4. KEY OBJECTIVE

To grow single crystal and eutectic turbine buckets without anomalies for less than 1650°C turbine inlet temperature and minimized grain boundaries for increased blade life.

5. PRINCIPAL CONTRIBUTION

Some replacement costs of ~ 4.5 $\overline{M}$/yr. Reduce fuel consumption; reduce air pollution. Some material development costs. Reduce fare of air transportation. Improve public safety.

6. LEVEL OF CONTRIBUTION

Public safety, national defense, public transportation, balance of payments.... all have some impact.

7. UNIQUENESS OF CONTRIBUTION

Space processing metallurigical methods offer new metals with unique temperature and strength properties. By increasing the temperature threshold of present turbine blade engines, the efficiency and lifetime of the engine would increase, thus, saving energy and reducing maintenance of the engine.

8. TIME FACTOR

~ Late 1980's

9. PRINCIPAL INSTALLATION

NEO Manufacturing facility.

10. PRINCIPAL TECHNOLOGY

Variation of earth metallurgical process adapted to space.

11. IMPACT SPECTRUM (TBD)

12. FRONT-END CAPITAL (TBD)

30. HIGH-STRENGTH PERMANENT MAGNETS

1. GENERAL CLASSIFICATION

Manufacturing of small space products.

2. GENERAL OBJECTIVE

The manufacturing of special terrestrially immissible metals for application to very high strength permanent magnets.

3. PRODUCT TO EARTH

New/unique alloys, e.g. AgMgAl or combinations of Fe, Al, Ni, Co, and Cu... that when magnitized have high/long lasting properties.

4. KEY OBJECTIVES

To produce terrestrial imissible alloys via solidification (metallurgy) methods in space.

5. PRINCIPAL CONTRIBUTION

Instrumentation industry, e.g., motors (long life) medical science, high strength has favorable affect on healing wounds.

6. LEVEL OF CONTRIBUTION

Electronic/medical industry

7. UNIQUENESS OF CONTRIBUTION

Imissible alloys would be unique to earth.

8. TIME FACTOR

~ 1985 - 1990

9. PRINCIPAL INSTALLATION

NEO manufacturing facility

10. PRINCIPAL FUNCTIONAL UNITS

Melt furnace.

11. PRINCIPAL TECHNOLOGY

Existing use in space.

12. IMPACT SPECTRUM (TBD)

13. FRONT-END CAPITAL (TBD)

31. THIN-FILM ELECTRONIC DEVICES*

AND

CONTINUOUS RIBBON CRYSTAL GROWTH*

* See Space Station Systems Analysis Study (MDC G 6508), Part 1, Final Report, Volume 3, Appendices, Book 1, Objective Data, McDonnel Douglas Corporation, pages 5-30 through 5-35 (September 1, 1976)

32. SPACE LIGHT PROGRAM: LUNETTA (1 OF 2)

1. OBJECTIVE: NIGHT ILLUMINATION BETWEEN 10 AND 100 MAXIMUM FULL-MOON BRIGHTNESS.
2. PRINCIPAL CONTRIBUTIONS:
   - ENHANCES FARMING PRODUCTIVITY; SOWING OF CROPS (15 TO 30 FULL MOON (FM)).
   - ECONOMIZES INDUSTRIAL OPERATIONS AT REMOTE SITES (15 TO 30 FM).
   - OUTDOOR LIGHTING FOR THOUSANDS OF COMMUNITIES AND VILLAGES IN DEVELOPING COUNTRIES (10 TO 20 FM).
   - LIGHTING OF URBANIZED REGIONS (45 TO 80 FM).
   - HIGH FLEXIBILITY IN PROVIDING ILLUMINATION QUICKLY ANYWHERE.

3. SYSTEM DESCRIPTION: LUNETTA CONSISTS OF A SINGLE (OR, LESS LIKELY, OF A SMALL CLUSTER) OF MODULARIZED ORBITING SOLAR REFLECTORS (MOSR). IT CONSISTS OF A STRONG RIM AND A SERIES OF SPOKES CONTROLLED FOR TENSION AT THE CENTER OF THE REFLECTOR. A CONCENTRIC RING STRUCTURE INTERCONNECTS THE SPOKES. THESE RINGS SUBDIVIDE THE GORES FORMED BY THE SPOKES, SERVING AS MOUNTS AND AXIS FOR THE REFLECTOR FACETS. BY ALLOWING A RELATIVELY SMALL TILT ANGLE ABOUT A PRESET POSITION OF NO MORE THAN FIVE DEGREES, DISTORTIONS IN THE SPOKES OR OF THE RIM CAN BE COMPENSATED. FOR LUNETTA AND SOLETTA, THE PRESET POSITION OF THE FACETS IS PLANAR, BECAUSE OF THE LARGE DISTANCE OF THE FOCAL POINT AT THE EARTH'S SURFACE. WEIGHT: 200 TO 300 TONS/KM^2 (0.04 TO 0.06 LB/FT^2).

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SPACE LIGHT PROGRAM: LUNETTA (2 OF 2)

● ORBIT: PERIODS	6,	8, OR	12 HOURS
: ALTITUDES	1.63	2.18	3.17 EARTH RADII (INCLINATIONS = 0.45 DEGREES)
● SUBSATELLITE AREA ILLUMINATED:	7,337	13,186	27,800 SQ. KM (1 KM^2 = 0.39 SQ. MI.)
● REFLECTOR AREA FOR FULL MOON BRIGHTNESS:	0.027	0.048	0.102 SQ. KM
● NUMBER OF LUNETTAS FOR AN 8 HR. ILLUMINATION:	4	3	2

4. SUPPORTING SYSTEMS:
   - TRANSPORTATION: SHUTTLE AND TUG OR SOLAR-ELECTRIC PROPULSION STAGE (SEPS).
   - ASSEMBLY: NEAR-EARTH ORBIT (NEO) ASSEMBLY COMPLEX.
   - DOMICILIARY: SPACE STATION(S) (NEO) FOR CREW SIZES OF 30 TO 45.
   - MAINTENANCE: AUTOMATED INTERORBITAL VEHICLE WITH MANIPULATORS OR TELEOPERATOR FOR ROUTINE TASKS. MANNED TUG FOR SPECIAL REQUIREMENTS.

5. PRINCIPAL TECHNOLOGY AREAS: LOW-WEIGHT STRUCTURES OF ADEQUATE RIGIDITY; ASSEMBLY AND TRANSPORTATION OF LARGE STRUCTURES IN SPACE; HIGH REFLECTIVITY AND LONG LIFE OF REFLECTING SURFACE; HIGH-SPECIFIC-IMPULSE ELECTRIC PROPULSION UNITS OF LONG LIFE FOR LUNETTA CONTROL. HIGH-PRECISION ATTITUDE POSITIONING.

6. SYSTEM PERFORMANCE: EACH SQUARE KILOMETER OF LUNETTA PROVIDES ILLUMINATION EQUIVALENT TO THE CONSUMPTION OF 13 MILLION BBL OF OIL ANNUALLY, CONVERTED TO ELECTRIC LIGHT (TAKING REFLECTOR LOSSES AND ATMOSPHERIC TRANSPARENCY INTO ACCOUNT), AT A SAVING OF ABOUT 21 BILLION BTU OF THERMAL OUTPUT. THUS, 1 KM^2 OF LUNETTA SURFACE, WHILE ILLUMINATING, CORRESPONDS TO THE OUTPUT OF A 900 TO 1000 MEGAWATT POWER STATION. EQUIVALENCE IS HIGHER AT CLEAR NIGHTS, LOWER AT HEAVILY CLOUDED NIGHTS. BECAUSE REFLECTOR FACETS ARE MOVABLE, LIGHT CAN BE DIFFUSED WHEN NOT NEEDED TO AVOID NUISANCE OR UNDESIRABLE EFFECTS ON WILDLIFE. INCLINED ORBITS PROVIDE ILLUMINATION FOR INDUSTRIAL ACTIVITIES IN FAR NORTH OR SOUTH DURING SUNLESS MONTHS (15 TO 30 FULL MOONS).

7. KEY SCHEDULES FOR INITIAL OPERATION IN 1987/89: 1975-80 R&D LARGE STRUCTURES; ELECTRIC CONTROL ENGINES; MATERIALS. SHUTTLE: 1980; ORBITAL TESTING AND DEMONSTRATION: 1981-83; SPACE STATION: 1983; COMMERCIAL PROTOTYPE DEVELOPMENT AND DEMONSTRATION 1984-88. OPERATIONAL DEPLOYMENT THEREAFTER.

8. FRONT END CAPITAL TO FIRST COMMERCIAL PROTOTYPE: APPROXIMATELY $15 BILLION (1975) OVER A 10 TO 12 YEAR TIME PERIOD.

33. SPACE LIGHT PROGRAM: SOLETTA FOR PHOTOSYNTHETIC PRODUCTION ENHANCEMENT (PSPE SOLETTA) (1 OF 2)

1. OBJECTIVE: ILLUMINATION OF SUFFICIENT MAGNITUDE TO STIMULATE PLANT GROWTH--20% TO 50% OF SOLAR INTENSITY
2. PRINCIPAL CONTRIBUTIONS:
   - DAYLIGHT EXTENSION OVER AGRICULTURAL AREAS IN REGIONS OF SHORT, COOL SUMMERS
   - NOCTURNAL CYCLING--INTERRUPTION OF NOCTURNAL PERIOD BY PERIOD OF ILLUMINATION TO STIMULATE PHOTOSYNTHESIS AT NIGHT
3. SYSTEM DESCRIPTION: PSPE SOLETTA CONSISTS OF A CLUSTER OF FREE-FLYING SOLETTA UNITS (SU) WHICH, IN TURN, MAY

3. SYSTEM DESCRIPTION: PSPE SOLETTA CONSISTS OF A CLUSTER OF FREE FLYING SOLETTA UNITS (SU). EACH SU MAY, IN TURN, BE AN ASSEMBLY OF STANDARD ELEMENTS (SE). EACH SE IS A MODULARIZED REFLECTOR OF 50 TO 200 KM^2 IN SIZE, DEPENDING ON THE OVERALL SIZE OF THE PSPE SOLETTA. WEIGHT: 100 TO 150 $TONS/KM^2$ (0.02 TO 0.03 LB/FT^2). USE OF ORBITAL MANUFACTURING PROCESSES IS POSTULATED.

SPACE LIGHT PROGRAM: SOLETTA FOR PHOTOSYNTHETIC PRODUCTION ENHANCEMENT (PSPE SOLETTA)

o ORBIT: PERIODS:	4,	6	OR	8 HOURS
ORBIT: ALTITUDES:	1.01	1.63		2.18 EARTH RADII (INCLINATIONS: 0 TO 45 DEG)
o SUBSATELLITE AREA ILLUMINATED	2793	7337		13,681 KM^2 (1 KM^2 = 0.39 SQ. MI)
o REFLECTOR AREA PER 10% SOLAR BRIGHTNESS	270	740		1,370 KM^2
o NR. OF SOLETTAS FOR 3-4 HR ILLUMINATION	3	2		1

4. SUPPORTING SYSTEMS:

- o TRANSPORTATION: AEROSPACE FREIGHTER (1000 TO 5000 TONS TO NEAR-EARTH ORBIT (NEO))
- o ASSEMBLY: NEO ASSEMBLY COMPLEX
- o DOMICILIARY: NEO SPACE STATION(S) FOR CREW SIZES OF 50 TO 150
- o MAINTENANCE: AUTOMATED INTERORBITAL VEHICLE (REMOTELY CONTROLLED) WITH MANIPULATOR ARMS OR TELEOPERATORS FOR ROUTINE TASKS. MANNED TUG FOR SPECIAL REQUIREMENTS

5. PRINCIPAL TECHNOLOGY AREAS: ESSENTIALLY THE SAME AS FOR LUNETTA, EXCEPT FOR STILL MORE STRINGENT WEIGHT LIMITATIONS

6. SYSTEM PERFORMANCE: BASIC SYSTEM DELIVERS TO SURFACE AN AVERAGE OF ABOUT 730 MEGAWATT RADIATION ENERGY (MWR) PER SQ. KM SOLETTA (90% REFLECTIVITY, 40% ATMOSPHERIC ABSORPTION). DETERMINATION OF THE ECONOMIC PERFORMANCE OF THE SYSTEM IS COMPLEX. A SIMPLIFIED EXAMPLE IS GIVEN: THE ECONOMIC PERFORMANCE DEPENDS STRONGLY ON THE EFFECTIVENESS OF THE KILOWATT RADIATION ENERGY (KWR) IN ENHANCING FOOD PRODUCTION. FOR A YIELD INCREASE OF \$11 PER ACRE AND SERVICING 1.8 MILLION ACRES (7285 KM^2, 2813 SQ. MI) ANNUALLY, THE VALUE INCREASE IN FOOD PRODUCTION WOULD RUN \$220 MILLION (1975) PER 100 KM^2 SOLETTA AREA. THIS WOULD COVER THE INITIAL AND RECURRING EXPENSES, PLUS CAPITAL AMORTIZATION ON AN ANNUAL BASIS OVER A PERIOD OF 30 YEARS ON THE ASSUMPTION THAT 1% OF THE SUNLIGHT DELIVERED TO THE GROUND (I.E. AFTER 90% REFLECTIVITY AND 40% ATMOSPHERIC ABSORPTION) IS PHOTOSYNTHETICALLY PRODUCTIVE. BUT TO ACHIEVE THIS PRODUCTIVITY, IT IS LIKELY THAT THE SOLETTA MUST BE SIZED FOR A NORMAL BRIGHTNESS OF AT LEAST 20% OF SOLAR BRIGHTNESS.

7. KEY SCHEDULES FOR INITIAL OPERATION IN 1995-2005: LUNETTA SCHEDULE APPROXIMATELY AS DESCRIBED UNDER "LUNETTA". ENVIRONMENTAL CONSENSUS (WHICH MAY OR MAY NOT BE NEEDED FOR LUNETTA) AND OTHER QUESTIONS AFFECTING SOCIAL ACCEPTANCE RESOLVED BY ABOUT 1985. ORBITAL TESTING AND DEMONSTRATION (USING SHUTTLE AND SHUTTLE-DERIVED HEAVY LIFT VEHICLE): 1985-90. DOMICILIARY FACILITIES, ASSEMBLY FACILITIES, TRANSPORTATION READY BY 1990. COMMERCIAL PROTOTYPE DEVELOPMENT AND DEMONSTRATION: 1990-95. OPERATIONAL DEPLOYMENT THEREAFTER.

8. FRONT END CAPITAL TO FIRST COMMERCIAL PROTOTYPE: \$30 TO 60 BILLION (1975) OVER A 20 TO 25 YEAR TIME PERIOD.

34. OIL SPILL DETECTION

GENERAL OBJECTIVE

Oil spill detection. Ocean and fresh water pollution from tanker and drilling platform catastrophes are easily detectable by existing means. Oil spills caused by vessels clearing the bilge and similar overboard dumping is virtually unnoticed, is common practice, and in the aggregate, is much greater than the major events. What is needed is a system to detect and identify these minor events so that corrective actions may be instituted and charged to the offenders.

PRODUCT TO EARTH

Timely identification of location and magnitude of covert or accidental contamination of navigable waters by oil, fuel, or other petroleum products. Causing the offender to pay the costs of cleanup, or instituting procedures and mechanisms to prevent spills would achieve multiple benefits to people, shellfish, water fowls, and commercial agencies that share the water resources.

KEY OBJECTIVE

Oil, ceing lighter than water, floats; recent investigations have shown that oil has a distictive spectral signature, showing a peak reflectance at about 4500 Å, easily distinguished from the surrounding water. A single photometer, at low altitude, detecting radiation in the band, would mark the time this occurred, reporting to a ground control center (Fairbanks) every orbit (polar). A number of small, short lifttime satellites, shuttle injected, would be an inexpensive solution.

PRINCIPAL CONTRIBUTION

Observation of extensive ocean and inland waters by satellite is much more cost-effective than aircraft or surface craft monitoring. The single ground station would receive reports not more than 90 minutes after occurrence, notifying the local authorities to take action.

LEVEL OF CONTRIBUTION

Near real time notification of offenses to local harbor, lake, river and coastal water authorities, apprehending and charging offenders for cleanup costs. Benefit to all people who use these waters, as well as all marine life, etc. Extension to high seas and other countries is inherent: this is a service that may be sold or traded for other considerations.

UNIQUENESS OF CONTRIBUTION

No other affordable monitor system can detect the minor offenders and police these waters.

TIME FACTOR

Design and construction of Oil Spill monitor satellites (initial system of 10 to 12) to be accomplished by Shuttle polar orbit operational capability.

PRINCIPAL INSTALLATION

Space only: small, battery-powered cold-gas stabilized satellites containing a single photometer restrictecd to 45 Å wave band. Limited lifetime (one year), low-altitude (approximately 100 mile). Ground: single ground control station to track satellites and collect reports (similar to Satellite Control Facility for DOD satellites).

PRINCIPAL FUNCTIONTAL UNITS

Approximately ten satellites injected by one Shuttle flight. Ninety-minute, high inclination orbit; may be recovered and refurbished, recharge batteries and gas system, by later Shuttle flights (about once per year).

PRINCIPAL TECHNOLOGIES

All needed technology exists.

IMPACT SPECTRUM

Technology: Design and build

Economy: Save millions of dollars by reducing oilspill damage. Few new jobs created, but existing enforcement practices greatly improved (productivity); exportable service to other nations. Environmental: reduce one significant cause of water pollution.

Social: Improve the servivability of water life-forms; positive reaction by environment protectionists.

Political: No additional national impacts; internationally, the service can be exported for goodwill, money or consideration.

CAPITAL TO IOC:

Space elements: about $50 M to design and build 10 to 12 satellites.

Ground element: About $25 M to install and $5 M per year to operate.

35. ICEBERG TRACKING

1. General Objective

Icebergs constitute a significant threat to shipping in the North Atlantic. The U. S. Coast Guard's International Ice Patrol has the responsibility for detecting and tracking icebergs, and notifying shipping. The icebergs are currently located by Coast Guard personnel flying C130's equipped with Side Looking Airborne Radar (SLAR). A C130 can cover approximately 15,000 square miles on each 8 hour mission. Approximately 150,000 square miles of ocean need to be searched. This operation could be accomplished on a continuing real-time basis by a microwave radiometer-equipped satellite in a geosynchronous orbit.

2. Product to Earth

Iceberg location data on approximately 1600 icebergs over 150,000 square miles - provided to the Coast Guard's iceberg plotting and tracking computer.

3. Key Objectives

Search planes are often grounded by storms. It is during storms that the iceberg move substantial distances, produce calves, and are are most difficult for ships to locate by radar. The spacecraft would monitor their locations continuously so as to enable their tracking.

4. Principal Contributions

Iceberg tracking by satellite would eliminate the need for flying patrols under hazardous conditions. While the computer will predict where the iceberg is expected to be, the patrol planes need to verify that it indeed is there.

4. Principal Contributions (continued)

If it isn't, search patrols need to be flown to relocate the iceberg. With continuous monitoring (or updates every 3 hours) icebergs would not be lost to present a hazard to shipping.

5. Level of Contributions

One ship saved in 10 years that would otherwise be lost could pay for the system. The cost of the iceberg patrol is borne by 19 maritime nations in proportion to the tonnage shipped through areas threatened by icebergs. The cost of the surveillance function of the International Iceberg Patrol is estimated to be $2.0M per year, or $20M over 10 years. While the cost of the satellite system would be greater than this, the service provided would be vastly supervior, and less hazardous.

6. Uniqueness of Contribution

Continuous and accurate coverage, particularly during storms, could not be readily provided by any other means.

7. Time Factor

Near Terms 1980 - 1990

8. Principal Installation

One satellite in geosynchronous orbit could provide continuous coverage of the entire North Atlantic region. The location data would be transmitted from the satellite to the computer installation on Governors Island.

9. Principal Functional Units

Constellation Size: 1

Orbit: Geosynchronous

Spacecraft

Weight: 30,000 lb

Power: 500 watts

Size: 14 ft dia x 10 ft len

800 ft dia antenna (cloud-penetrating frequency)

10. Principal Technologies (Al Love?)

Microwave radiometer resolution technology--space construction technology

11. Impact Spectrum

a. Technical — System requires modest advance c er current SOTA. Technology could be used for other applications such as geothermal mapping (Steve Cerri?)

b. Economic: Reimbursement protocol already exists. Increased knowledge of ocean currents could aid in optimum route planning.

c. Environmental: Possibility of oil pullution of fishing grounds reduced

d. Social: Elimination of currently hazardous duty by Coast Guard.

e. Political: Increased international good-will.

f. Scientific: Increased knowledge of ocean currents.

12. Front-End Capital

Acquisition Cost	$400M
Launch Cost	100M
Annual Operating Cost	(incremental) 0

36. COASTAL COLLISION AVOIDANCE RADAR

1. General Objective

In certain coastal regions the density of shipping traffic is very high and the danger of collisions substantial. 150 ships pass every day through the Malacca Strait which varies in width from 10 to 40 miles. Conventional radar is too expensive and interference prone. Two satellites 90° apart in geosynchronous orbit could illuminate potential collision areas with scanning microwave beams from space, to enable ships to obtain range and angle data on hazards.

2. Product to Earth

Microwave signals to enable detection of hazards.

3. Key Objectives

All objects greater than 100 square meters within 12 n.mi. range would be detected within a 300 foot accuracy.

4. Principal Contribution

Reduce collision hazards with associated loss of life, cargo, and oil pollution of fishing areas.

5. Level of Contribution

Electronic navigational aids are being developed and installed in the Malacca Straits. Experience with navigational aids in Calcutta harbor reveals that $7000 navigational bouys are ruined by thieves who are after 50 cents worth of copper wire. The space system would be independent of ground or sea-based navigational aids. Conceivably, one ship collision could be avoided every year at an estimated saving of $50M to $200M per year. Over the 10 year life, this would amount to $500M to $2B.

6. <u>Uniqueness of Contributions</u>

The system would give positive, all weather location of shipping in the straits.

7. <u>Time Factor</u>

Need is now (1980-85) but system assembly technology and capability will not be available according to currently scheduled activities until 1985-1995.

8. <u>Principal Installations</u>

A special radar would be located on board ships plying the straits. Two satellites would be located in geosynchronous orbit, 90° apart. Each would consist of a phased array sending a 100 kw pulsed signal in the X-band. The area covered would be 200 x 200 n.mi.

9. <u>Principal Functional Units</u>

Ground: Special radar (3 ft x 0.5 ft antenna) on board ships

Space:

Constellation size: 2 (90° apart)

Orbit: geosynchronous

Spacecraft: (Each)

Weight: 100,000 lbs

Size: 1000 ft x 1000 ft

Power: 150 kw

10. <u>Principal Technologies</u>

Further analysis of the basic concept, and on-orbit assembly and transport capability of large space objects.

11. <u>Impact Spectrum</u>

a. Technical: Experience gained would be applicable to assembly of larger space structures

b. Economic: Need to devise plan for financial reimbrusement. Need further analysis of cost-benefits. Preserve fishing economy along straits.

c. Environmental: Substantial impact in reducing threatened oil pollution of vital fishing grounds as result of tanker collisions.

d. Social: Aid in the preservation of viable fishing-based life style along straits.

e. Political: Mutual international cooperation for self-interest conducive to peace.

f. Scientific: Serendipitous discoveries likely.

12. <u>Front End Capital</u>

Ground: $20,000 per ship

Space:

Acquisition Cost: $1.0B

Transportation Cost: $300M

Annual Operating Cost: --

37. ICEBERG TOWING BY UNMANNED TUGS

1. GENERAL OBJECTIVE

To tow icebergs to warm areas that need fresh water.

2. PRODUCT TO EARTH

Cost effective supplies of fresh water using icebergs.

3. KEY OBJECTIVES

If the tugs could be unmanned but remotely controlled from space, they could be considerably cheaper. Perhaps even wind power could be used along with nuclear or fossil fuel power.

The astronauts aboard a space station would utilize powerful optical telescopes and other sensors to search out large icebergs of the proper shape and location (aspect ratio ~ 3 to 1 in northern Antarctic waters). Once the proper candidate is located, tugs which use a combination of wind and fossil fuel power would be attached to the iceberg. Once attached, the tugs would be unmanned and would tow it to the desired location.

Powerful sensors and computers aboard the manned space station will be used to sail the tugs. Remote teleoperator devices will drive the necessary mechanisms and optimize route and use of engines versus sails. Since they move so slowly, several sailboats can be operated simultaneously by an astronaut on a part-time basis.

4. PRINCIPAL CONTRIBUTIONS

To bring an abundance of fresh water and some electrical power to warm climate sea-coast cities/areas. One example would be to make desertous areas of the earth fertile and productive by supplying them with abundant quantities of water and power.

One method for supplying electricity and fresh water to dry coastal areas would be to tow large icebergs into the area from Antarctic waters. The temperature differential between the iceberg and the surrounding water provides the electricity; the ice when it has melted provides the fresh water.

5. LEVEL OF CONTRIBUTION

Could be a multi-billion dollar enterprize.

6. UNIQUENESS OF CONTRIBUTION

TBD (How effective could a man in space be in optimizing the route, sail Vs. power, etc. of several icebergs in tow at one time; how cheap could you build mammoth sail tugs if they did not have to be man-rated; and what are the iceberg/tug interfaces --- i.e., how do you grab the thing?). Note: The attachment and ultimate destination installation is a manned operation; only the main trip is unmanned.

7. TIME FACTOR

Mid-1990's.

8. PRINCIPAL FUNCTIONAL UNITS

Space System Characteristics

- Weight = _____ kg space station (shares many other duties)
- Size = Small space station, 20-mm optical telescope; transponder tracking system for each tug
- Power =
- Orbit = Geosynchronous, or polar inclination, latitude location = _______________
- Constellation size = One space station (30 sail-powered tugs with teleoperation capabilities)

Ground Tugs - Basically a system of several tugs with the iceberg as a part of the system. It may be necessary to use the iceberg itself as ballast to counteract wind pressure on the sail. This is the key area --- can the sail/diesel-powered tug system be very economical to build?

9. PRINCIPAL FUNCTIONAL UNITS

Space station, ocean tugs.

- Towing interval ~ 6 months
- 12 to 15 icebergs in tow at any given moment
- Space telescope resolution = 20 meters (clear conditions)
- Power production = _______ kWh per iceberg (_____ kW continuous)
- Water production = __________ liters/iceberg (_______ liters per day) ~ Chicago's consumption level

10. PRINCIPAL TECHNOLOGICAL AREAS

Quality optical systems (many other uses possible), unmanned sail-powered tugs, remote teleoperation devices to capture and tow the iceberg, power generation systems utilizing the inherent temperature differential. Extremely cheap, simple, reliable, wind-powered tugs would be key to the economics of the system.

11. IMPACT SPECTRUM

Danger of collisions in sea lanes with other ships. Little environmental impact since the iceberg water is a very small part of the ocean. Virtually no pollution. Potential of creating new cities with associated local food production where location for energy efficiency or other reasons is optimum.

12. FRONT-END CAPITAL

TBD

38. GLOBAL SEARCH AND RESCUE

1. GENERAL OBJECTIVE

To locate small, lightweight emergency transmitters.

2. PRODUCT TO EARTH

Location of person or vehicle in distress for rescue

3. KEY OBJECTIVES

When an aircraft, ship, etc., is down or lost, the search is costly, time consuming, and often unsuccessful. This would show the location quickly, accurately, and continuously.

4. PRINCIPAL CONTRIBUTIONS

Principally lives saved. Sometimes equipment saved also.

5. LEVEL OF CONTRIBUTION

Small, not a major factor nor a large number of lives involved. (However, very important to you if you are the one who is lost.)

6. UNIQUENESS OF CONTRIBUTION

This depends on the user. Large ships and aircraft know location continuously (or will with GPS) and could send out this information on ordinary emergency chanels. Small vehicles usually have emergency transmitters, but may not be able to accurately communicate their position.

7. TIME FACTOR

Mid 1980's.

ORIGINAL PAGE IS OF POOR QUALITY

8. PRINCIPAL INSTALLATIONS

A system of high altitude nav/comm satellites to allow the use of small, inexpensive, lightweight emergency transmitters. The satellites transpond the signals from the emergency transmitter and the location is computed by time difference of arrival on the ground site. The emergency transmitters can be very tiny, weighing a pound or two and having a continuous life for at least a month self-contained. Each transmitter would have stored a unique code out of a catalog of 100 or more codes stored in the ground cross-correlation receivers. The transponders have 100 frequency-multiplexed channels.

• Weight	2,000 lb
• Size	5 x 7 ft
• Raw Power	500 W
• Orbit	Near-Synchronous or Medium Altitude
• Constellation Size	20
• Life/Servicing Period	10/3 Years

9. PRINCIPAL FUNCTIONAL UNITS

Space satellites, similar to a Comsat or GPS satellite, except with larger antennas. The ground transmitters are small enough to be carried by everyone venturing away from popular areas, such as hikers, pleasure boats, or cars traveling between cities. A much more modest system for use only by official vehicles or aircraft could use a single channel transponder and time-share a few correlator receivers.

10. PRINCIPAL TECHNOLOGIES

Primarily a question of economics. How cheap and small can you make the ground units?

11. IMPACT SPECTRUM

Not significant

12. FRONT-END CAPITAL (TBD)

39. BORDER SURVEILLANCE SYSTEM

1. GENERAL OBJECTIVE

To detect overt or covert attempts at crossing a border, either a political boundary or other border such as a large military installation, western ranch, etc.

2. PRODUCT TO EARTH

Number and location of crossings.

3. KEY OBJECTIVES (Note that military objectives are not a part of this study)

The differences in political systems, lifestyles, resources, etc., have made border violations, particularly between US and Mexico, a massive and continuing problem. These crossings have major economic implications (jobs, etc.) and also moral problems (drugs, etc.). The objective of this system would be to make an illegal border crossing very difficult.

4. PRINCIPAL CONTRIBUTIONS

The major problem of unemployment in the US will be reduced and the also major problem of drug addiction (and corresponding crime) will also be reduced.

5. LEVEL OF CONTRIBUTION

Illegal border crossings from Mexico into the United States are curren.', / . The Los Angeles Police Department estimates that over a million illegal Mexican aliens will be in Los Angeles by 1981; of course, their children will be citizens. Without control, this will most likely increase as the economic despairity between the countries widens and as US treatment of spanish minority groups improves. Our health, education, and welfare policies make entry into this country *irresistibly attractive* according to the Los Angeles Times* The estimated cost of the drug related crime in the United States is /year. A large fraction of these drugs come from Mexico. The Los Angeles Police Department studies indicate that almost 20 percent of crimes in Los Angeles are committed by illegal aliens. A space system could reduce the illegal personnel crossings by as much as 75 percent.

6. UNIQUENESS OF CONTRIBUTION

As USSR has demonstrated, this objective can be effectively achieved without a space system. The space advantage, if any, would therefore be in economies or social advantages.

7. TIME FACTOR

Needed ASAP. Reasonably available IOC by 1990.

8. PRINCIPAL INSTALLATIONS

The main segment is on the ground with approximately a million small sensors that are read-out by a large antenna satellite at GSO.

9. PRINCIPAL FUNCTIONAL UNITS

The ground are small (0.5 Kg) seismic sensors spaced approximately 30 feet apart to form an electronic *fence*. The space unit has the following basic characteristics:

- Weight 3,400 lb
- Size 5000 ft x 10 ft
- Raw Power 12 kw
- Orbit Synchronous Equator
- Constellation Size 1

*January 30, 1977.

10. PRINCIPAL TECHNOLOGIES

Large structures in orbit and extremely cheap, reliable sensors on the ground. The economies of the ground units probably needs a breakthrough in cost/performance.

11. IMPACT SPECTRUM

The influx of illegal aliens into the United States from Mexico is a major and increasing cause of unemployment and social problems. Also, the hard drug problem is considered by some to be one of the most devastating social/moral issues in the United States since its principal victum is a young person, and its normal effect is to create a desparate criminal.

12. FRONT-END CAPITAL

Total system cost is in range of hundreds of millions, including ground sensors. Operating costs should be low.

D. INTERNATIONAL LAW AND SPACE INDUSTRIALIZATION

APPENDIX D:

INTERNATIONAL LAW AND SPACE INDUSTRIALIZATION

(A memorandum by Delbert D. Smith, J.D., Ph.D., Madison, Wisconsin)

MEMORANDUM

TO: Rockwell International, Space Division

SUBJECT: International Law and Space Industrialization

The present memorandum,* which is designed to explore the impact of international space law upon the future industrialization of outer space, is divided into four main segments. First, the concept of space industrialization is outlined. Second, existing international agreements affecting the utilization and development of outer space are examined in terms of their respective influences on various types of space industrialization. Third, current negotiations relating to the formulation of international guidelines for the use of outer space for particular purposes, including direct television broadcasting, satellite remote sensing, and exploitation of lunar resources, are assessed both as a means of projecting possible international legal regimes in those particular areas, and for identifying trends which could affect other types of space utilization. Finally, recommendations for actions designed to facilitate space industrialization are discussed.

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*The views and conclusions contained in this memorandum are those of the author and do not necessarily reflect or represent the views or policies, either expressed or implied, of any organization, agency, or group.

PART I: THE CONCEPT OF SPACE INDUSTRIALIZATION

For purposes of the present memorandum, the concept of space industrialization is used in a broad sense to encompass an extensive array of possible uses of outer space. Five main categories of activities are encompassed.

A. Communications Services

The success of recent communications technology applications programs conducted by NASA[1] and the prospects for resumption of NASA communication satellite experimentation indicate that technical and economic feasibility for a large number of innovative communications services is likely to be achieved in the near future. Among the communications activities which are projected for near- or middle-term satellite implementation are:

1. teleconferencing;
2. direct television broadcasting;
3. electronic mail;
4. electronic funds transfer;
5. improved data communications;
6. business and home communications systems incorporating computers and small-scale receiving terminals;
7. improved mobile communications for personal and vehicular use;
8. medical information services, including telediagnosis, patient monitoring and access to medical records;
9. improved disaster warning services based on enhanced remote sensing and meteorological applications; and
10. search and rescue communications.

Although not exhaustive, this listing indicates the scope of future possibilities for the utilization of outer space, and particularly the geostationary orbit,[2] for communications.

B. Remote Sensing Services

Public and private experimentation in the satellite remote sensing area centering around NASA's Landsat Program has demonstrated the feasibility of using satellites for the acquisition of data relating to the earth and its environment. The breadth of experimental activities has facilitated identification of an extensive listing of potential applications and services.[3] Set forth below is a listing of a number of the general categories into which these applications may be divided:

1. Mineral resources monitoring;
2. Ocean resources management, including living and non-living resources;
3. Crop surveys, including insert and disease monitoring and yield projections;
4. Land use management;
5. Population surveys;
6. Monitoring of pollution in the atmosphere, rivers and streams and oceans;
7. Weather and climate forecasting; and
8. Non-meteorological disaster forecasting.

C. Satellite Power Systems

The 1973 embargo on the export of petroleum products to certain oil-consuming countries imposed by members of the Organization of Petroleum Exporting Countries (OPEC) and subsequent events, including energy shortages, increasing energy costs and their economic, social and foreign policy implications, have promoted the search for cost-effective, alternative energy sources. One possibility is the establishment of generating facilities in orbit which would relay resultant energy to the earth's surface using a microwave or laser transmission system. Three main alternative methods of power generation are under consideration: solar energy, nuclear fission and nuclear fusion. Relay of electrical power generated either in space or on the earth's surface via satellite to secondary receivers constitutes another option for the industrialization of space.

D. Space Manufacturing

A number of experiments relating to physical and chemical properties of matter in outer space conducted during NASA's Skylab program indicate that certain unique characteristics of outer space, including weightless, vacuum and extreme temperature differentials, may permit the manufacture of products which either could not be produced on the earth or would be of significantly inferior quality. A number of specific benefits have been identified, including:

1. production of superior electronic products, especially semiconductor crystals;
2. pure vaccines and other pharmacentical products;
3. improved laser glass and optics manufacturing;
4. production of alloys of metals which are otherwise immiscible in their respective liquid states;
5. production of superconductors;
6. assembly and maintenance of large space structures, including space stations and vehicles.[4]

E. Deep Space Operations

In contrast to the operations described above which would be most likely to occur at altitudes above the earth between 100 and 22,300 miles, a number of activities relating to the development of outer space could be undertaken advantageously beyond that limit. Perhaps most important of these is the mining of minerals on the moon and other celestial bodies.

PART II: APPLICABLE INTERNATIONAL AGREEMENTS

International space law applicable to the space industrialization activities described in Part I is embodied in a series of treaties and conventions adopted primarily under the auspices of the United Nations. The fundamental Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies[1] resulted from initiatives within the United Nations and after several years of negotiation was signed in 1967. In subsequent years, other treaties were negotiated to elaborate the basic principles defined in the 1967 treaty. Perhaps most important from the perspective of space industrialization is the Convention on International Liability for Damage Caused by Space Objects, which entered into force for the United States in 1973.[2]

I. TREATY ON PRINCIPLES GOVERNING THE ACTIVITIES OF STATES IN THE EXPLORATION AND USE OF OUTER SPACE, INCLUDING THE MOON AND OTHER CELESTIAL BODIES

The 1967 Outer Space Treaty provides the foundation for the legal framework for all activities beyond the upper limits of national airspace jurisdiction. Consequently, its provisions are relevant to the consideration of all four major categories of space industrialization. Particular consideration should be given to the provisions governing:

1. permissible uses of outer space (Articles I, IV and IX),

2. non-appropriation of outer space (Article II);

3. applicability of international law (Article III);

4. military uses of outer space (Article IV);

5. responsibility of states for the acts of nationals in space (Article VI);

6. international liability for damage caused in space (Article VII);

7. the exercise of national jurisdiction in outer space (Article VIII); and

8. relations between states relating to their respective space activities (Article IX).

A. Article I

Article I, which establishes the most basic principles governing activities in outer space, provides:

> The exploration and use of outer space, including the moon and other celestial bodies, shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development, and shall be the province of all mankind.
>
> Outer space, including the moon and other celestial bodies, shall be free for exploration and use by all States without discrimination of any kind, on a basis of equality and in accordance with international law, and there shall be free access to all areas of celestial bodies.
>
> There shall be freedom of scientific investigation in outer space, including the moon and other celestial bodies, and States shall facilitate and encourage international co-operation in such investigation.

1. *Article I(1): The "Common Interests" Clause*

Paragraph 1 raises two main issues: first, whether this provision constitutes a binding contractual obligation or is merely declaratory of general objectives, and second, regarding the meaning of the phrase "for the benefit and in the interests of all countries." Related to the former is the question whether the provision is self-executing. Some authorities argue that although the so-called "common interests" clause of Paragraph 1 embodies one of the most fundamental principles upon which the outer space regime is founded, its breadth precludes direct application. Consequently, other, more limited expressions of international consensus are required to give this provision enforceable form. Under that approach, pending agreement on specific operative principles elaborating the fundamental policy of Article I(1), any use of outer space would be permitted under Article I(2), provided it is peaceful in nature.[1]

A contrary conclusion is reached by a number of other authorities who take the position that the language of Article I(1) is binding upon the signatories, as is any provision of an international treaty. Two main reasons are advanced to support this proposition. First, during consideration of the text of the provision in the fifth session of the Legal Sub-Committee of the Committee on the Peaceful Uses of Outer Space (CPUOS), a proposal to delete the phrase "for the benefit and in the interests of all countries" from Article I and place it in the preamble was rejected.[2] Similarly, the draft of Article I(1) was modified when the words "irrespective of their degree of economic or scientific development" were moved on the basis of a consensus from initial position in the preamble to their present position following the "common interests" clause, because the developing countries advocated inclusion of the latter phrase as part of the binding treaty commitment.[3] Thus, it may be inferred that the drafters intended Article I(1) to be binding. Second, even if the provision is considered non-self-executing and the effectiveness of the limitation is thereby somewhat diminished, its binding character is not impaired and the legislative or executive acts necessary to implement the binding provision are nonetheless mandatory for all parties to the treaty.[4]

The content of the phrase "for the benefit and in the interests of all countries" in Article I(1) is also open to dispute. Some authorities take the position that the treaty's admonition to use outer space for the benefit of all members of the international community constitutes no more than a duty upon each member not to misuse outer space in a way which could diminisn the value of space activities to other members.[5]

Others have taken the closely related position that the phrase means that the use of space objects should not be detrimental to the interests of other countries, including national security, public order and sovereignty over natural resources which are protected under international law.[6]

The third possible interpretation would impose on space powers the obligation either to permit other countries to use the former's space vehicles or to share the financial benefits of its space activities. Arguments supporting this position have been raised in the discussions of the CPUOS Legal Sub-Committee relating to direct broadcast and earth resources satellites.[7] To date, that approach has received little direct international support.[8] Nonetheless, a similar approach relating to the exploitation of resources in another area located beyond the limits of national jurisdiction, the deep seabed, has received substantial support during the present series of United Nations Conferences on the Law of the Sea.[9] Although a scheme for licensing exploitation of the orbit and distributing the proceeds equitably among the members of the international community has been proposed, current developments in space law and the law of the sea suggest that final agreement on such an arrangement is not likely to occur in the near future.

An analysis both of relevant arguments and of trends in the interpretation of Article I(1) as it applies to the utilization of outer space for industrial purposes indicates a number of conclusions. First, as an operative element of a treaty, Article I(1) is binding upon all states which are parties to the treaty. Second, the content of the "common interests" clause is unclear and therefore requires further elaboration. As a result, the clause may be considered non-self-executing for purposes of space industrialization. Third, although the clause's content is disputed at a minimum, it imposes a duty upon states to use outer space in such a way that neither the earth-bound interests of other states, including national security, or the potential interests of the latter in the exploration or use of outer space are jeopardized. Finally, although the upper limit of the "common interests" requirement is unclear under existing space law, Article I(1) does not require space powers to share either their space vehicles or the profits derived from space activities with non-space powers.

The impact of Article I(1) upon space industrialization depends on the precise nature of the activity contemplated. Communications satellites utilize segments of the electromagnetic spectrum and portions of the geostationary orbit. Although both are potentially subject to overcrowding, unilateral use of transmission frequencies or orbital slots would not violate Article I(1), since transmitter and space shuttle technology and the potential ability to remove inoperative satellites from orbit emphasizes the character of both the spectrum and the geostationary orbit as renewable resources-which are non-depletable in any permanent sense. Most applications would not jeopardize any of the essentially terrestrial interests protected by Article I(1). However, some nations have argued that the use of satellites for the transmission of television programs directly to home or community receivers could interfere with the internal political or economic stability of "receiving states."[10] Although some concern may be justified despite good faith efforts by all participating parties, the question will be decided in the context of a separate declaration relating to direct broadcast satellites, rather than in the context of Article I(1).

The impact of "common interests" clause on satellite remote sensing is likely to be somewhat similar to its effect on communications applications. Although some sensing satellites--primarily those designed for earth resources applications--operate in low earth orbit, others, including meteorological satellites, are likely to occupy geostationary orbital slots. As noted above, use of the geostationary orbit consistent with the applicable regulations of the International Telecommunication Union (ITU) is not impeded by Article I(1). However, some questions have arisen regarding interference with the national security and economic interests of sensed states arising from potential abuses of earth resources applications of remote sensing technology. As a result, efforts to limit the use of earth resources satellites or to place their use in the context of a somewhat restrictive organizational structure have been initiated in the United Nations.[11] Although reference has been to Article I(1) in the debates, the result of these debates is likely to take the form of an international declaration of principles which does not refer directly to the content of that provision.

If satellite power systems are implemented either experimentally or operationally, four main questions are likely to arise in the context of the "common interests" clause. First, since such systems are likely to occupy segments of the geostationary orbit to facilitate either power production or transmission, and since the size of such satellites will require significantly larger slots than are presently utilized by communications and meteorological satellites, the question of orbital slot allocation will undoubtedly arise. However, Article I(1) does not present an obstacle. Second, as presently conceived, a satellite power system would not affect adversely a state's sovereignty over its natural resources, its political, social, cultural and economic self-determination or domestic order among its citizens. Consequently, those interests would not inhibit establishment and operation of a satellite power system. A third potential concern could arise among energy-producing countries that the establishment of such systems by energy-consuming countries could undermine the economies of the former. However, as suggested below in Section I.C., international law does not protect countries against either economic competition or economic pressure.

Finally, the laser or microwave transmission mechanisms likely to be used by satellite power systems to convey power generated in orbit to relay stations on the earth's surface may be said to constitute potential weapons for use against the earth's surface. If the weapons potential were realizable, the system *qua* weapon would be contrary to the interests of non-allied countries protected by Articles I(1) and IV. However, the assumption of the present memorandum is that satellite power systems will incorporate adequate safeguards to prevent their use as weapons and hence would not violate the interests of other states embodied in Article I(1).

Operation of manufacturing facilities in outer space would not adversely affect any of the terrestrial interests of states with the possible exception of adverse economic influence resulting from the relative scarcity of products manufactured in outer space and the accompanying high cost. As noted above, this fact is insufficient in itself to present any restriction on space operations. Since manufacturing facilities would not necessarily require placement in geostationary orbit, interference with the space-oriented interests of non-participating states in access to particular areas of outer space is not likely to occur. However, since those facilities are likely to generate various forms of waste ranging from harmless gases to debris and nuclear by-products, potential interference with the space activities of other states, the provisions of Articles I(1) and IX probably require the operation entities to take reasonable steps to identify and avoid such potential interference.

In addition to the interpretation of the "common interests" clause an assessment of the impact of Article I(1) on the use of outer space for industrial purposes raises a set of issues centering around the argument that Article I(1) requires states to use outer space "for exclusively peaceful purposes."[12] Even assuming for the purposes of this analysis that the Article I(1) requirement that outer space be used "for the benefit and in the interests of all countries" contains within it the requirement that outer space be used "exclusively for peaceful purposes,"[13] the United States' position on the question significantly diminishes the extent to which the latter requirement could inhibit the industrialization of outer space. However, pressure from other governments could lead to general acceptance of a more restrictive approach.

The main point of contention is the meaning of the term "peaceful uses." Regardless of their respective positions on the question of content, authorities agree that the main interpretational alternatives are limited to two: "peaceful uses" can be defined either as "non-aggressive uses," leaving open the possibility of the use of outer space for defensive military purposes or as "non-military uses," excluding both aggressive and defensive activities.[14]

The possibility that Article I(1) implicitly incorporates the "peaceful use" requirement is based on the language of that provision and on the context in which the treaty was drafted. Applying the requirement that space activities be conducted "for the benefit and in the interests of all countries" to the question of military action in outer space, some authorities conclude that the space activities can be conducted in the interests of all countries only if they are "peaceful" in nature.[15] In addition, it may be argued that since the term "peaceful" is ambiguous and subject to conflicting interpretations, especially in the context of a general statement of desirable purposes of space initiatives, the drafters chose to substitute the concept of use "in the interests of all countries."[16] Finally, proponents of the "peaceful use" requirement maintain that since Article IV and other provisions of the treaty did not completely prohibit placement of weapons in outer space, the term "peaceful uses" was omitted from Article I to avoid ambiguity.[17]

The case for the opposite position is based on the formulation of Article IV, which in Paragraph 2 expressly limits activities on the moon and other celestial bodies to exclusively peaceful purposes, but in Paragraph 1 omits any such limitation. Although some advocates of the "peaceful use" interpretation of Article I(1) explain the omission as the result of imprecise drafting,[18] the omission must be considered intentional since an attempt to apply the phrase "exclusively for peaceful purposes" to all areas of outer space was defeated.[19] Since the Article IV approach is expressly stated, and is supported by the "free use" principle of Article I(2), it cannot be altered by inferences based on less explicit language.

Similar arguments apply to the dispute regarding the definition of "peaceful uses." In support of the "non-military" interpretation it is argued that military activity can never be "peaceful" and even purely defensive weapons cannot be in the interests of all states.[20] On that basis, it is argued that adoption of Article I(1) embodying the expression of one of the most fundamental principles of space law operates to prohibit even defensive weapons in outer space.[21]

The opposite view is based on the contention that "non-aggressive" uses are permitted, first, by Article IV(1) which prohibits the stationing of weapons of mass destruction in outer space but omits the express requirement of peaceful uses applied by Article IV(2) to the celestial bodies, and second, by Article III which requires states to conduct space activities in accordance with international law, including the United Nations

Charter. Neither prohibits defensive or non-aggressive military activity. Support for this approach is also found in the practice of states. Both major space powers use outer space for military communications and reconnaissance. Although these activities are "military" in nature, they are "non-aggressive."

Balancing of these arguments and the underlying policy considerations leads to the conclusions:

1. that although Article I(1) requires states to conduct space activities "for the benefit and in the interests of all countries," it does not prohibit all military activity in outer space; and
2. that Articles I(1), III and IV combine to limit any military activity in outer space to "non-aggressive" conduct.

These conclusions suggest that under present international space law, stationing military installations and weapons systems in orbit may be permissible if they are defensive in nature and do not contain nuclear weapons or other instruments of mass destruction. Hence, the operator of a satellite power system may be permitted to convey its products to orbital or terrestrial military installations which are designed for defensive purposes. The need to distinguish defensive from offensive purposes may present a problem for the system operating in this context. Finally, if used exclusively in conjunction with defense-oriented systems and installations, the system may be operated by military personnel.

In general, activities relating to space industrialization are not in themselves either ggressive or defensive as those terms are used in a military context and hence would not violate the alleged requirement that outer space be used exclusively for peaceful purposes. However, in some cases, non-space powers may argue that direct television broadcasting and satellite remote sensing constitute "aggressive" activities and should therefore be restricted. In the absence of other facts, however, the current state of international law in this area would not support these contentions.

Although not "aggressive" on their face, space industrialization activities may be deemed aggressive because of the uses made of the resulting products. The generations of electrical power in orbit is illustrative for these purposes.

Satellite generated power could be put to three arguably military uses:

1. directly as a weapon used to attack terrestrial or space targets for aggressive or defensive purposes;
2. to provide energy for the support of military installations and weapon systems in orbit or on earth; or
3. to relieve civilian demand on terrestrial power generation facilities to ensure an adequate supply of energy to terrestrial military installations.

The first use constitutes the main subject matter of Section III.D. of Part II and is examined there in the context of Article IV of the Outer Space Treaty. The connection of the third possible use to military activities is too tenuous to support application of the prohibition of any military use of outer space inferred by some authorities from the language of Article I(1). In addition, a parallel approach could be used to prohibit national exploitation of the minerals of the deep seabed for civilian use, since that could increase the supply of minerals available to the nation as a whole and hence to its military organizations. That result is, however, directly contrary to the express provisions of the international legal regime of the high seas which both reserves use of the deep seabed for exclusively peaceful purposes and authorizes exploitation of seabed minerals without reference to their possible use for military purposes.[22]

Thus, only the second possibility--that of direct use of satellite generated power by military installations or weapons systems--poses a potential problem under the alleged requirement that outer space be used exclusively for peaceful purposes. If some or all of the power is used by an orbital weapons system which clearly is in violation, for example, of the Article IV(1) prohibition on the stationing of weapons of mass destruction in orbit or by a military installation located on a celestial body in violation of Article IV(2), the use of outer space for generating power would be unlawful to the extent that its power products are consumed by the prohibited system installation. The result is less clear when the power products are consumed by a military installation or weapons system which is either legally in orbit or is located on the earth. If power generated by a satellite is utilized by a military installation or weapons system which is legally in orbit,[23] the use of outer space for the power generation activity would be permissible under the "free use" principle of Article I(2). The legality of the stationing of the installation or weapons system in question must be determined by reference, first, to the specific prohibitions of Article IV, and second, to the debate regarding the content of the alleged "peaceful use" requirement.

As set forth in greater detail in Section I.D. below, Article IV specifically prohibits a series of three activities in outer space:

1. the stationing of nuclear weapons or other weapons of mass destruction in orbit around the earth or elsewhere in outer space;
2. the stationing of such weapons on the moon and other celestial bodies;
3. the use of the moon and other celestial bodies for any except exclusively peaceful purposes; as a result, the establishment of military bases, installations and fortifications, the testing of weapons of any kind and the conduct of military maneuvers in those areas is forbidden.

As suggested above, some authorities argue that the Article I(1) requirement that outer space be used "for the benefit and in the interests of all countries" includes a requirement that space be used exclusively for peaceful purposes. If that argument can be sustained, the activities of states in outer space would be further limited. The extent of the limitation would depend on whether all military activities or only aggressive activities would be prohibited.

2. *Article I(2): The "Free Use" Principle*

The second paragraph of Article I contains two main provisions which are likely to influence the industrialization of space. The most important, the "free use" principle, provides that "outer space, including the moon and other celestial bodies, shall be free for exploration and use by all States . . . ." This "free use" principle provides the international legal basis for all activity in outer space. In contrast to the restrictions imposed by other sections of the Outer Space Treaty, Article I(2) affirmatively authorizes space activities, and hence serves as the point of departure for any argument in favor of a particular use of outer space. For that reason Article I(2) has played an important role in the protection of space initiatives against unnecessary restrictions.

Thus, although the "free use" principle is one of the key provisions of the Outer Space Treaty, and is sufficiently broad to sustain the right of states to conduct activities in outer space free from claims of sovereignty of subjacent states, it is not unlimited.

As suggested above, Article I(2) must be read in the context of the "common interests" clause of Article I(1) with the result that the advantages to be derived from rapid development of outer space must be balanced against the requirement that the development be carried out in a manner beneficial to all members of the international community. In that combination, the "free use" clause creates a tendency to limit the potential inhibiting effect of a restrictive construction of Article I(1). As applied to the industrialization of outer space, the "free use" principle has provided the conceptual basis for resisting arguments that activity in outer space is unlawful in the absence of clear and convincing evidence that it is being conducted for the benefit and in the interest of all countries in accordance with Article I(1).[24] Consequently, Article I(2) tends to shift construction of Article I(1) toward the minimal duty to avoid conducting space activities in a manner detrimental to the interests of non-participating states as described above. In addition, the "free use" principle is subject to the prohibitions both of Article II relating to non-appropriation and of Article IV dealing with the stationing of nuclear weapons in outer space. To the extent that space industrial activities are likely to contaminate either outer space or earth, the "free use" principle is also limited by Article IX.[25]

B. Article II: Non-Appropriation in Outer Space

The second major limit on the "free use" principle is embodied in Article II, which provides:

> Outer space, including the moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means.

The non-appropriation principle is likely to affect the activities associated with space industrialization which involve either consumption of space resources or utilization of the geostationary orbit. The language of Article II raises three main issues with respect to industrial development in space:

1. the subject matter to which the prohibition applies;
2. the meaning of the term "appropriation"; and
3. the validity of "appropriation" by entities other than national governments.[26]

The listing of space industrial activities set forth in Part I contains two types of resource utilization. First, satellite power systems arguably "appropriate" solar energy. However, with respect to solar energy the Article II prohibition clearly does not apply. One of the primary purposes of Article II is to implement the "free use" policy of Article I(2).[27] Article II must therefore be construed to promote rather than inhibit the exploration and use of outer space. Nearly all satellites presently in service or planned for the near future will depend on conversion of the sun's energy to electrical power for use in the operation of their respective payloads. Large-scale use of alternative energy sources by satellites has proven impractical. As a result, application of the Article II prohibition to the use of the sun's energy would sharply limit the scale, duration, and hence, the economic viability of space development projects. Further, in the absence of special circumstances, enforcement of Article II against the "appropriation" of essentially inexhaustible space resources would serve little purpose,[28] and should be avoided in favor of the "free use" principle. Since the same policy considerations apply to conversion of solar energy for use on earth as well as for use by satellites in orbit, Article II probably does not limit the use of solar energy by satellite power systems.

Second, extraction of mineral ores and other substances from the moon or other celestial bodies, which may eventually constitute one of the most significant commercial space activities, arguably constitute "appropriation" in violation of Article II. As noted below,[29] both the United States and the Soviet Union have taken the position that although Article II prevents a country from exercising sovereign control over portions of the moon, it does not interfere with exercise of proprietary rights over natural resources after they have been separated from the moon's surface or subsurface. However, the interpretation of Article II is a central issue in the negotiations relating to the draft moon treaty before the CPUOS Legal Sub-Committee. Final resolution of the dispute which has delayed conclusion of the moon treaty will also depend on establishment on the question of potential rights of each member of the international community to exhaustible lunar resources.

The second category of space industrial activities which could be significantly affected by Article II require utilization of the geostationary orbit. In theory, earth resources and communications satellites, and satellite power systems could be said to "appropriate" segments of the geostationary orbit.

The use of a particular orbital slot is undoubtedly subject to the terms of Article II, especially in light of its function of providing support to the "free use" principle. The question is most pressing for orbital power generation, and the analysis below applies a fortiori to other satellites in geostationary orbit. Because of the projected dimensions of a solar power satellite,[30] the size of the orbital slot required for safe operation is substantially greater than that required for existing communications or meteorological satellites. In addition, stress factors resulting from the necessary length of support beams suggest the need for safety zones similar in concept to those established for installations engaged in exploitation of the resources of submarine areas.[31] Although the Article II prohibition clearly applies to the appropriation of a particular orbital slot, the determination of the validity of placing a solar power satellite in geostationary orbit is dependent on the meaning of the term "appropriation" as used in Article II.

Analysis of the concept of "appropriation" suggests the existence of two subsidiary elements:

1. exclusive use; and
2. relatively permanent use, including consumption.[32]

It has been argued that since use of a particular orbital slot by a geostationary satellite is temporary, the requirement of permanence is absent and the use of the orbital slot cannot be considered an "appropriation" within the meaning of

Article II.[33] Other authorities conclude that national use of particular segments of the orbital arc deprives other states of the opportunity to use the same area and therefore constitutes appropriation through occupation.[34] The key issue is the permanence of the use. Evaluation of the economic viability of a satellite power system is based on the assumption that the system would operate for up to thirty years.[35] Although that period is extended, it does not indicate the permanence necessary to invoke the prohibitions of Article II. However, longer periods could exceed the limit and come within the purview of Article II.

The third issue raised by the Article II prohibition focuses on the identity of the system operator. Article II appears to prohibit only national appropriation, suggesting that even permanent use of an orbital slot by international organizations or commercial entities would not necessarily constitute a violation of that provision.[36] Consequently, a commercial consortium would not be prohibited under Article II from maintaining a solar power, earth resources or communications satellite in a particular orbital slot for an indefinite period. Similarly, subject to establishment of a clear distinction from other types of organizations, an "international" organization would not be prohibited either from operating a similar system or allocating orbital slots among its members. For that reason, the activities of the International Telecommunication Union described below in Section III relating to the management of the geostationary orbit do not violate Article II.

Three potential limitations on these conclusions should be noted. First, the interpretation set forth above would not permit commercial or international organizations from claiming exclusive rights to a particular area of outer space in the absence of actual use. Thus, if such an organization had maintained a satellite in a specific orbital slot for a substantial period of time and the satellite's station-keeping systems subsequently failed, the organization would not be entitled to prevent any other entity from occupying that slot pending orbiting a replacement satellite by the original occupant. Second, if an entity were established which although commercial in form was essentially under the control of the government of the country in which it is organized, permanent use would constitute national, as distinguished from non-national, appropriation.[37] Third, dispute has arisen regarding the minimum standard of universality which would determine whether an international organization would be implicitly exempted from the rule of non-appropriation. Professor Jenks has argued that only the United Nations as a representative of the whole international community should be exempt.[38] Presumably any intergovernmental organization of relatively universal membership satisfies the minimum standard. However, some question remains regarding the exemption of an organization composed of a limited number of governments.[39]

Thus, the Article II prohibition against the appropriation of oute space applies to exclusive use of a segment of the geostationary orbit. However, the prohibition does not apply to the activities of either non-governmental entities or relatively comprehensive international organizations. The implications of the non-appropriation provision for space industrial activities are further limited by the conclusion that since the use contemplated is not permanent, exclusive use for a limited period of time would not constitute "appropriation" as that term is used in Article II. Hence, regardless of the operating entity's institutional structure, it can expect to conduct industrial activities in geostationary orbit without concern that its action violates Article II.

C. Article III

Another fundamental principle affecting the utilization of outer space is the general applicability of international law as embodied in Article III, which provides:

> States Parties to the Treaty shall carry on activities in the exploration and use of outer space, including the moon and other celestial bodies, in accordance with international law, including the Charter of the United Nations, in the interest of maintaining international peace and security and promoting international co-operation and understanding.

As suggested in Subsections A and B above, Article III, through its reference to the United Nations Charter, affects industrial development of outer space, first, because it prohibits the aggressive use of military force, and second, because it does not prohibit the use of economic leverage for political purposes. In both cases, the key is Article 2(4) of the United Nations Charter which provides:

> All Members [of the United Nations] shall refrain in their international relations from the threat or use of force against the territorial integrity or political independence of any state, or in any manner inconsistent with the purposes of the United Nations.

Interpretation of this provision in light of the remainder of the Charter suggests that the use of armed force is prohibited, except under certain specified circumstances when the use of force in self-defense is authorized.[40] Consequently, under Article III use of outer space for defensive purposes is not prohibited. That conclusion is strengthened by the language of Article IV as described below in Section I.D.

In connection with the analysis of Article I(1) in Section I.A. above, it was suggested that international law would not prohibit the operator of a space industrial facility from engaging in economic competition with other countries which produce similar products or from using the availability of the products of those facilities to exert economic pressure on consuming countries as a means of political persuasion. Construction of Article 2(4) of the Charter limiting its prohibition to the use of armed force is a significant part of the conceptual underpinnings of that proposition. The conclusion that economic leverage is not prohibited under Article 2(4) is supported by significant authority.[41] In addition, that conclusion is consistent with prevailing general international law.[42] As a result, the system operator need not be concerned that any means of selecting or limiting consumers of the system's products contravenes existing international law.

D. Article IV

Some of the applications listed in Part I could be converted to military purposes. Article IV of the Outer Space Treaty, which limits these possibilities, provides in part:

> States Parties to the Treaty undertake not to place in orbit around the earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction, install such weapons on celestial bodies, or station such weapons in outer space in any other manner.

The language of Article IV raises two main issues:

1. the implications for industrial development of outer space of the Article IV prohibition against the stationing of weapons of mass destruction in orbit; and
2. the impact on Article IV on plans to establish military facilities in orbit for the protection of a satellite power system from attack.

In Section I.A.2. above, analysis of Article IV in the context of the concept of the exclusive use of outer space for peaceful purposes suggested, among others, the conclusion that Articles I(1) and IV(1) implicitly authorize the establishment of military installations and weapons systems in outer space -- but not on the celestial bodies -- which are exclusively defensive in nature, provided they do not contain nuclear weapons or other weapons of mass destruction. Of the activities described in Part I, only satellite power systems and their microwave or laser transmission beams appear likely to be adaptable for direct use as weapons. The possibility that the products of industrial facilities in outer space could be used for military purposes is discussed in Section I.A.2. above.

Because of the nature of the transmission beam, the argument may be made that the establishment of a satellite power system potentially constitutes the stationing of a weapon of mass destruction in outer space in violation of Article IV. The system operator can make at least three responses. First, the system is designed not as a weapon but as a utilitarian device for the efficient use of solar resources. Any of the present designs incorporates a series of safety devices to terminate transmission of power when the transmission beam moves outside the intended reception area.[43] Although the selection of a laser transmission beam could constitute a safety hazard, the tendency among designers is toward the use of a microwave beam which is considered less dangerous.[44] Nonetheless, the potential harm from a microwave beam should not be underestimated.[45] Second, in geostationary orbit the satellite's configuration and location would limit its use as a weapon. Third, the system is not likely to be operated by military or national security entities and is therefore less susceptible to use as a weapon. Thus, although use of a satellite power system as a weapon is clearly prohibited under Article I.V.(1), the probability of such use as well as the value thereof is rather small.

Application of Article IV to the establishment of military installations in space to protect space industrial facilities is somewhat more complex. Once established, space industrial facilities, especially those in geostationary orbit, would present a desirable target for military or terrorist action. The large size of power generation and manufacturing structures would increase the margin of error for targeting purposes and therefore decrease the level of military sophistication required to ensure reasonable probability of a successful attack. In addition, the potential importance of industrial facilities to a nation's economic, political and military potential suggests that destruction of the system would be assigned a high priority in time of military or political conflict. Finally, because an attack on the system could create significant social and political impact without jeopardizing human life, the system would represent a desirable target for symbolic actions.

In theory, Article VII of the Outer Space Treaty and the procedure established in the Convention on International Liability for Damage Caused by Space Objects would provide remedies for any damage except that caused by actions taken against the system not involving a space object. A laser attack originating from a terrestrial installation is a possible example. However, the procedures established by treaty are not likely to be effective, especially in cases of deliberate destruction. First, extensive delays must be anticipated prior to resumption of service, with obvious consequences for the launching state's economic stability. Second, since diplomatic claims settlement procedures are involved, full recovery of damages specified in Article XII of the Convention in Liability is not likely, first, because damage claims are often discounted, and second, because few countries have the economic capacity to repay the cost of establishing a space installation. Third, a successful attack could create potential hazards from debris in space and, in the case of satellite power systems, from transmission beam spillover on the earth's surface.

In light of the foregoing considerations, some means of military protection is considered desirable. Terrestrial weapons systems are likely to be limited in their ability to defend space installations against attack either from outer space or from the earth. Hence, some form of defensive weapons system stationed in space in a position to protect the satellite power system appears necessary.

In Section I.A.2., an analysis of Articles I(1) and IV and the concept that outer space should be used exclusively for peaceful purposes led to two main conclusions:

1. the stationing of nuclear and other weapons of mass destruction in outer space is prohibited;
2. military activity in outer space is not prohibited if it is defensive or non-aggressive in nature.

The same principles apply to the establishment of a weapons system in space for the protection of the space segment of space industrial facilities. In principle, Articles I(1), III and IV do not prohibit the establishment of such a weapons system provided it does not incorporate weapons of mass destruction or require the use of installations on the moon or other celestial bodies.

Some difficulty could arise, however, if a protective system were incorporated which purported to be defensive in nature but which could be trained on earth or other celestial bodies, or upon large space objects and used for aggressive as well as defensive purposes. Although it could be argued that the exigencies of national security and modern warfare require such flexibility, the dual purpose approach would undermine the rationale for omitting defensive weapons systems from the prohibitions of Article IV. As a result, such systems may be considered unlawful to the extent that they are capable of inflicting mass destruction.

E. Article VI[46]

Article VI, which establishes the foundations for international responsibility for activities in outer space provides:

> States Parties to the Treaty shall bear international responsibility for national activities in outer space, including the moon and other celestial bodies, whether such activities are carried on by governmental agencies or by non-governmental entities, and for assuring that national activities are carried out in conformity with the provisions set forth in the present Treaty. The activities of non-governmental

> entities in outer space, including the moon and other celestial bodies, shall require authorization and continuing supervision by the State concerned. When activities are carried on in outer space, including the moon and other celestial bodies, by an international organization, responsibility for compliance with this Treaty shall be borne both by the international organization and by the States Parties to the Treaty participating in such organization.

Thus, each state which is a party to the treaty is charged with the obligation, first, to ensure that the activities of its nationals comply with the provisions of the treaty, and second, to accept responsibility for those activities which contravene applicable provisions. In this manner, states are unable to avoid the duty of compliance through the use of institutional configurations which do not involve elements of the national government.[47] Consequently, the responsibility of each state's government is not affected by the juridical character of the entity actually operating the satellite power system.

A state's duty to supervise the activities of its nationals for practical purposes probably prohibits unregulated, private undertakings.[48] Article VIII of the Outer Space Treaty reinforces the obligation by requiring the state under whose registry an object is launched into outer space to retain control and jurisdiction. In light of the potentially hazardous character of many activities related to industrial development in outer space, especially satellite power generation, the policy considerations underlying Article VI suggest the need for relatively strict supervision.[49] The provisions of Article VII and the Convention on International Liability for Damage Caused by Space Objects,[50] which impose liability on the launching state for damage resulting from space activity, are likely to give rise to practical and foreign policy considerations which create pressure upon national governments to exercise the supervision necessary to ensure protection against the potential hazards of orbital power generation.

Although governments are required to ensure compliance of their respective nationals with appropriate provisions of the treaty, Article VI does not have the effect of subjecting non-governmental entities to provisions which would otherwise not apply to them. For example, as suggested above in Section II.A., Article II does not apply either to private sector entities or to international organizations. Although terms of Article VI require states parties to the treaty to ensure compliance of their nationals with its provisions, Article VI does not extend the prohibition against appropriation to entities which are not covered by the terms of Article II.

F. Article VII

Article VII, which embodies the fundamental principles governing liability for danger arising from space activities, provides:

> Each State Party to the Treaty that launches or procures the launching of an object into outer space, including the moon, and other celestial bodies, and each State Party from whose territory or facility an object is launched, is internationally liable for damage to another State Party to the Treaty or to its

natural or juridical persons by such object or its component parts on the Earth, in air space or in outer space, including the moon and other celestial bodies.

Because of the wide range of potential environmental and other hazards which could be created by establishment and operation of space industrial facilities, the question of liability is particularly significant. Potential injuries include:

1. Damage to body tissue of humans and wildlife exposed to nuclear and electromagnetic radiation;
2. Radio frequency interference;
3. Interference with electronic instrumentation, especially devices associated with medical, navigation, and explosives detonation activities; and
4. Environmental modification, including weather and climate alteration, resulting from increased heat generation and interaction of the transmission beam and launch vehicle exhausts with the upper atmosphere and ionosphere.[51]

If injury results from the operation of a satellite power system, the injured party is entitled to redress under Article VII. Under its terms, the state which procured the launch of the vehicle causing the injury and the state which launched the space object are internationally liable to the entity actually injured, or to its national government. The language of Article VII raises two main issues:

1. the meaning of the word "damage"; and
2. the meaning of the phrase "internationally liable."

Although the terms of Article VII provide no guidance on these issues, the broad principles of Article VII were implemented in the Convention on International Liability for Damage Caused by Space Objects. Since Article VII raises no issues which are distinguishable from those raised by application of the Liability Convention to space industrialization, discussion of the Article VII principles is incorporated in Section II of this Part, which examines the Liability Convention.

G. Article VIII

Article VIII of the Outer Space Treaty, pertaining to the ownership and control of objects in outer space provides:

> A State Party to the Treaty on whose registry an object launched into outer space is carried shall retain jurisdiction and control over such object, and over any personnel therefor, while in outer space or on a celestial body. Ownership of objects launched into outer space, including objects landed or constructed on a celestial body, and of their component parts, is not affected by their presence in outer space or on a celestial body or by their return to the Earth. Such objects or component parts found beyond the limits of the State Party to the Treaty on whose registry they are carried shall be returned to that State, which shall, upon request, furnish identifying data prior to their return.

The first sentence assists implementation of the provisions of Articles VI and VII relating to international responsibility and liability for activities in outer space, particularly over nationals operating in non-governmental capacities. Although the nature and scope of national control is likely to vary from country to country, possibly giving rise to a "flag of convenience" practice in outer space, Article VIII is likely to introduce or increase regulatory limitations on industrial development in outer space. Consequently, entities which are interested in participating in the development of outer space should anticipate that current developments in regulatory concepts and practices are likely to serve as precedents for regulation of space activities. Hence, those entities should consider whether regulatory developments in relevant areas, both substantive and geographic, should be monitored for purposes of identifying trends and formulating plans for participating in the evolution of regulatory structures.

The second sentence is considered extremely important to institution of operational industrial services in outer space. By protecting the rights of ownership as established in accordance with traditional international law, Article VIII provides the basis for industrialization of outer space under both commercial and national governmental organizational structures. As suggested below in Section IV, the capital investment necessary to develop, establish and operate a satellite power system would be deterred or completely prevented if rights of ownership are not protected.

H. Article IX

Article IX, the final provision of the Outer Space Treaty which is likely to affect the industrialization of outer space, provides:

> In the exploration and use of outer space, including the moon and other celestial bodies, States Parties to the Treaty shall be guided by the principle of co-operation and mutual assistance and shall conduct all their activities in outer space, including the moon and other celestial bodies, with due regard to the corresponding interests of all other States Parties to the Treaty. States Parties to the Treaty shall pursue studies of outer space, including the moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter and, where necessary, shall adopt appropriate measures for this purpose. If a State Party to the Treaty has reason to believe that an activity or experiment planned by it or its nationals in outer space including the moon and other celestial bodies, would cause potentially harmful interference with activities of other States Parties in the peaceful exploration and use of outer space, including the moon and other celestial bodies, it shall undertake appropriate international consultations before proceeding with any such activity or experiment. A State Party to the Treaty which has reason to believe that an activity or experiment planned by another State Party in outer space, including the moon and other celestial bodies, would cause potentially harmful interference with activities in the peaceful exploration and use of outer space, including the moon and other celestial bodies, may request consultation concerning the activity or experiment.

Like Article II, Article IX operates as a limit on the "free use" principle of Article I(2). The key provision contained in the first sentence of Article IX requires states to "conduct all their activities in outer space . . . ., with due regard to the corresponding interests of all other States Parties to the Treaty.[52] The remaining three sentences implement the "due regard" requirement.[53]

The limitation contained in the first sentence is particularly relevant to the use of the geostationary orbit, where the problem of conflicting uses is complicated, first, by potential interference among satellites which are located in proximity to one another, and second, by disputes between countries which intend to use a particular orbital slot in the present or the near future and countries which plan to use the same slot in the more distant future and which are therefore concerned about preserving their future interests. In an effort to promote resolution of these potential conflicts, Article IX provides the basis for consultation among the concerned parties.[54] The general policies of Article IX are applied to the utilization of the geostationary orbit by the International Telecommunication Convention and the Radio Regulations periodically revised by ITU conferences.

The second sentence, which requires states parties to the treaty to conduct activities in outer space so as to avoid both harmful contamination of outer space and adverse changes in the earth's environment resulting from the introduction of extraterrestrial matter, could limit operation of space industrial facilities, if liberally construed. On its face, the second sentence is limited to environmental hazards potentially created by extraterrestrial <u>matter</u> brought within the earth's biosphere. Although the distinction between matter and energy is not yet precisely defined for these purposes, the passage of the satellite power system transmission beam, for example, through the earth's atmosphere appears to fall outside the scope of the second sentence.

However, the combination of the first two sentences may have the effect of extending the prohibition to the introduction of any physical phenomenon which could adversely affect the earth's environment. The first sentence implicitly incorporates at least conceptually the requirement of Article I(1) that outer space be used "for the benefit and in the interest of all countries."[55] To the extent the two provisions are coextensive, the first sentence would require space powers to conduct their space activities in a manner which does not prejudice the "corresponding" interests of non-participants. The definition of the term "corresponding" is not clarified, but presumably encompasses both space and terrestrial interests likely to be affected by space activities, in a manner comparable to the "common interests" clause of Article I(1).[56] Consequently, Article IX requires that consideration be given to the elimination of the adverse effects listed above,[57] especially to the extent they effect the interests of states other than the state conducting the activity in question.

The third and fourth sentences establish a minimum standard for "due consideration." If the state undertaking the activity has reason to believe that activities planned by its nationals are likely to cause harmful interference with the activities of other states parties to the treaty, it is obligated to "undertake appropriate international consultations" with the affected states prior to implementation of its plans. Similarly, if one party has reason to believe that the activities of another party would cause potentially harmful interference with activities relating to the exploration and use of outer space, the former may request such consultations, even if its own activities would not be adversely affected.[58] The consultation provisions raise three key issues:

1. when does a party have sufficient "reason to believe" that harmful interference would result from the planned activities?
2. what constitutes harmful interference?
3. what are the characteristics of "appropriate international consultations?

Under the language of the third sentence of Article IX, the obligation of a state planning to engage in space activity becomes operative when it has "reason to believe" that execution of plans would cause harmful interference with the activities of other states in outer space. Thus, the determination that the obligation has become operative is solely within the discretion of the launching state. If it lacks sufficient information relating either to interference factors or to the plans of existing space activities of other states, the launching state is authorized to proceed without consultation.[59] The scope of this discretion may be limited, however, by communications from states whose space activities would be adversely affected or from third states to the launching states informing the latter of potential interference and requesting consultations as provided in the fourth sentence of Article IX.

Article IX does not provide a clear standard for determining when the activities of one state "could cause potentially harmful interference" with the activities of another. The language of the third sentence suggests that only interferences with the space activities, as distinguished from the earth-bound activities, of another state are relevant; however, since a large proportion of space activity necessarily involves support activities on the earth's surface, interference with those also gives rise to the consultative obligation of Article IX.[60] Further, interference can only occur with respect to activities which constitute "peaceful uses of outer space."[61] Presumably, the term "interference" is used in its ordinary meaning to signify conflicting uses resulting in obstruction, creation of significant hazards or significantly diminishing the efficiency of space activities.

The characteristics of "appropriate international consultations" are left undefined. From the context, the term "consultation" refers to the joint examination -- including the exchange of relevant information -- of the proposed activities and the probable consequences for each consulting party's interests.[62] Since the term "consultation" was selected by the drafters of Article IX, the parties are obliged only to make a good faith effort to conduct the joint examination with a view to reaching satisfactory resolution of conflicts among the consulting states. However, Article IX imposes no obligation to achieve reconciliation.[63] Although the form or forum of consultation is not significant, the consultation must involve either diplomatic or scientific elements of the affected governments. As emphasized by the use of the word "international," the duty to consult is primarily bilateral in nature although consultation under the auspices of an intergovernmental organization is not precluded.[64] The suggestion that Article IX consultation must include all parties to the Outer Space Treaty cannot be supported.[65]

Thus, Article IX would require operators of space industrial facilities to conduct their activities with due regard at least to the space activities of other states. Although that requirement is likely to affect most directly the use of the geostationary orbit, it imposes a duty to remain alert to the possibility of adversely affecting the space interests of other states. In those cases where adverse consequences are likely, the operator is required to consult in good faith with the affected parties, with a view to the elimination of those consequences. However, the Article IX duty to enter into appropriate consultations does not impose an obligation to accept unnecessary restrictions on the operation of industrial facilities in space. Nonetheless, participation in such consultations by the government of the state whose nationals are conducting the space operations in question must be anticipated. Such participation is likely to limit the flexibility of space industrialists in their consultations, by applying pressure based on national foreign policy interests.

II. CONVENTION ON INTERNATIONAL LIABILITY FOR DAMAGE CAUSED BY SPACE OBJECTS

Article VII of the 1967 Outer Space Treaty established a basis for the imposition of liability for damage or injury caused by a space object. However, due to the general nature of its provisions, Article VII did not create specific principles directly applicable to damage actually resulting from space activity. In an effort to formulate appropriate principles, the Committee on the Peaceful Uses of Outer Space (CPUOS) stepped up its consideration of questions of liability. As a result, a draft convention was submitted to the General Assembly and adopted on November 29, 1971, in Resolution 2777 (XXVI).[1] The convention entered into force for the United States on October 9, 1973.[2] In its present form, the convention contains six main sections:

1. Articles I-VII establish the fundamental principles of liability and scope of coverage;
2. Articles VIII-XX set forth guidelines for presentation and prosecution of claims;
3. Article XXI provides for special assistance in the case of damage on a massive scale;
4. Article XXII generally applies the rules of liability to international intergovernmental organizations;
5. Article XXIII limits the convention's impact on other international agreements; and

6. Articles XXIV-XXVIII establish the procedures for signature, amendment and entry into force of the Convention.

A. Articles I-VII

Article I contributes to the delimitation of the scope of the convention, through its definitions of "damage" and "launching state." Article I(a) defines "damage" to mean

> loss of life, personal injury or other impairment of health; or loss of or damage to property of States or of persons, natural or juridical, or property of international intergovernmental organizations . . . .

Although undoubtedly covering damage directly resulting from launch or operation of a space object, that language leaves open the question whether the definition covers consequential or non-physical damage.[3] Since many of the potential damage categories associated with space industrialization[4] are either consequential or non-physical in nature, the ambiguity is significant for entities potentially involved in space activities. A survey of relevant authority suggests that the range of damage categories intended to be covered is relatively broad.[5] Consequently, impairment of mental and social well-being are likely to be covered.[6] Loss of consortium, other forms of "moral" damage, as well as forms of non-physical damage, including electronic interference are probably not covered.[7]

The second element of Article I which contributes to the definition of the convention's scope is Paragraph (c) which defines the term "launching State" to mean:

> (i) A State which launches or procures the launching of a space object:
>
> (ii) A State from whose territory or facility a space object is launched . . . .

This definition is significant, since the liability described in subsequent articles is imposed on the "launching State." The content of Article I(c) is based on Article VII of the Outer Space Treaty and is consistent therewith. As discussed in greater detail below,[8] the possibility that liability could be imposed on three separate governments for damage caused by a space object raises procedural complications which must be antipated.[9]

Another ambiguity is created by the definition in Article I(d) of the term "space object," which provides:

> (d) The term "space object" includes component parts of a space object as well as its launch vehicle and parts therof.

Although by its terms, Article I(d) clearly covers a launch vehicle and each of its components, as well as a "space object" and its components, the language does not provide clear guidance regarding the nature of a "space object." The term is used in the Outer Space Treaty to describe objects launched into outer space (Articles VII and VIII), objects in orbit around the earth (Article IV) or objects which are simply launched (Article X).[10] Natural objects such as asteroids are probably excluded unless some means of independent propulsion were constructed on it.[11] Similarly, a question may be raised regarding the status of objects which are manufactured or assembled in orbit.

Other limits on the applicability of the convention are contained in Article VII, which excludes from coverage:

> (a) Nationals of [the] launching State;
>
> (b) Foreign nationals during such time as they are participating in the operation of [a] space object from the time of its launching or at any stage thereafter until its descent, or during such time as they are in the immediate vicinity of a planned launching or recovery area as the result of an invitation by that launching State.

As a result, nationals of the launching state are limited to the judicial or administrative remedies provided by the law of the launching state. Presumably foreign nationals participating in the launch, operation and recovery of a space object would be limited to the same remedies.

Once it is ascertained, first, that the injury sustained falls within the scope of the term "damage" and resulted from the operation of a "space object" as those terms are defined in Article I, the convention imposes liability upon the "launching State." The nature of the liability depends upon the location at which the damage occurred. Thus, if a space object causes damage on the surface of the earth or to an aircraft in flight, Article II provides that the "launching State shall be absolutely liable to pay compensation" for the damage. In that case no proof of negligence is required and the launching state is liable even though it is able to demonstrate that it complied with all applicable standards of care.[12] Thus, if industrial activities in space result in injuries or damage to property on the earth's surface or while travelling in an aircraft, the launching state would be liable to pay compensation upon demonstration

1. that the injury occurred; and
2. that it resulted from the operation of space industrial facilities.[13]

The rationale for absolute liability is, first, that space acitivity is "ultrahazardous," and necessarily involves a risk of serious harm which cannot be eliminated by the exercise of utmost care,[14] and second, that the ability of a claimant state to demonstrate fault on the part of a launching is likely to be relatively limited.[15]

A possible weakness in the protection granted by Article II is based on the contention that it appears to not cover damage in airspace which does not affect aircraft in flight.[16] This omission is partially remedied by the likelihood that damage in the earth's atmosphere will result in injuries on the earth's surface which would constitute "damage" as that term is used in the Liability Convention. However, liability may be avoided by establishing that "the damage has resulted either wholly or partially from gross negligence or from an act of omission done with intent to cause damage on the part of the claimant State or of natural or juridical persons it represents," as provided in Article VI(1). In contrast, if damage is suffered in outer space, the launching state is liable for compensation to the injured party under the terms of Article III only upon a demonstration of fault of the launching state or of persons for whom it is liable.[17] The rationale for differing treatment is based on the contention that the absolute liability imposed under Article II would be inappropriate for collisions between space objects, since the operator of the more costly object would collect the difference between the values of the space objects, even if the collision were caused completely or preponderantly by the acts of the more costly space object.[18] However, as a practical matter, the difficulty of demonstrating fault is likely to mean that in the event of damage to space objects, each party is likely to bear its own loss except in exceptional cases.[19] For both Articles II and III, the measure of damages is determined under Article XII which provides that when compensation is granted under the convention, the amount

> shall be determined in accordance with international law and the principles of justice and equity in order to provide such reparation . . . as will restore the person, natural or juridical, State or international organization on whose behalf the claim is presented to the condition which could have existed if the damage had not occurred.

Articles IV, V and VI introduce refinements of the general framework established in Articles II and III. Under Article IV(1), if damage is caused somewhere other than on the surface of the earth to the citizens of one state or their property as the result of the activities of a second state, and that interaction results in injury to the citizens or property of a third state, the first two are jointly and severally liable to the third state. If under Subparagraphs (a) and (b), the damage to the

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third state occurs on the surface of the earth or to aircraft in flight, the liability is absolute; however, if damage is sustained by the third state's space objects to passengers or property on board, liability is based on fault. Paragraph 2 of Article IV apportions the liability between the first two states according to the extent to which each was at fault. If no comparative fault can be established, the liability is divided equally. Nonetheless, Article IV(2) expressly preserves the right of the third state to seek the entire compensation from any of the states which are jointly or severally liable.

Article V defines liability in cases in which two or more states jointly launch a space object. Under paragraph 1, all participating states are jointly and severally liable. After a state has paid compensation for damage caused by a jointly launched space object, it is entitled to seek compensation from other participants in the joint launching. The extent of each participant's liability may be determined by agreements among the participants, but such agreements do not prejudice the right of the state whose nationals have sustained damages to seek the full compensation from any or all of the launching states. Paragraph 3 includes among the participants the states from whose territory or facility a space object is launched. The language of Article V provides little guidance with respect to the definition of a joint launching. For example, the question may be raised whether a state is a participant or a joint launching state if:

1. it is responsible for a relatively minor experiment package on board the space object;
2. its nationals manufacture or supply a minor component part; or
3. it is represented at launch by a technical observer.[20]

Finally, Article VI exonerates a launching state from absolute liability if it can establish that the damage resulted either wholly or partially from gross negligence or from an act or omission done with intent to cause damage which may be ascribed to the claimant state or to the natural or juridical persons which it represents. However, Paragraph 2 prevents exoneration where the damage resulted from activities of the launching state which were not conducted in accordance with the applicable principles of international law, especially the United Nations Charter and the Outer Space Treaty.

Two main problems of construction are raised by the terms of Article VI. First, the meaning of "gross negligence" is left undefined and is subject to dispute. Second, the question may be raised whether exoneration from absolute liability under Article VI(1) relieves the launching state from all liability. Some contend that Article VI(1) should be construed to relieve liability only to the extent that the conduct of the nationals of the claimant state caused the damage in question.[21]

B. Articles VIII - XX

Articles VIII through XX of the Liability Convention establish procedural guidelines for the presentation and prosecution of claims. Article VIII identifies the states which are entitled to advance claims. Paragraph 1 authorizes the state which has actually sustained damage or whose nationals have suffered personal injury or property damage to present a claim for compensation. However, under Paragraph 3 if the state of nationality has not presented a claim, the state in whose territory the damage occurred may demand compensation, regardless of the nationality of the entity actually sustaining damage. If neither of the first two governments has sponsored or stated its intention to sponsor a claim, any state may present a demand for compensation for damage actually suffered by any of its permanent residents.

Article VIII has the effect of expanding the traditional rule that only the state of nationality is authorized to present a claim for damages.[22] However, the number of authorized claimants presents three main problems. First, Article VIII does not define the period of time within which the state of nationality or the state within whose territory the damage occurred must act to preserve its right. Second, Article VIII(2) does not require the latter to ascertain whether the state of nationality intends to present a claim.[23] Finally, the text of this article does not solve the question of authorized representation if under Paragraphs 2 or 3 a claim is properly presented and the state of nationality presents a subsequent claim. This question is particularly important to space industrialists, in light of the general rule that a state presenting an international claim is not obligated to pay any compensation to the party actually injured.[24] If the state of nationality were permitted to recover compensation from the launching state, the injured party could reasonably expect that political and economic considerations would motivate the state of nationality to convey all or part of the compensation to its injured nationals. However, if the state in whose territory the injury actually occurred recovers, the injured party would have a diminished prospect of recovery, since it would possess a limited ability to exert effective political pressure. This concern is diminished somewhat by the terms of Article XI(2) which permits the injured party to seek redress in the courts or administrative tribunals of the launching state.

Article IX places the claims procedure on a diplomatic basis, subject to the provision for judicial or administrative relief contained in Article XI(2). Time limits for the presentation of claims are established in Article X which has the effect of establishing a one-year statute of limitation measured from the date of occurrence or the date of identification of the launching state, or the date on which the claimant state could reasonably be expected to have discovered those facts through the exercise of due diligence. However, in cases in which the full extent of the damage is not immediately determinable, the claimant state is entitled to revise the claim and submit additional documentation until one year after the full extent of the damage is known.

Article XI(1) introduces an innovation into the practice of states regarding international claims. Traditional rules require the claimant to exhaust available local remedies prior to the presentation of the claim through diplomatic channels.[25] However, for the types of injuries covered by the convention, Article XI(1) expressly nullifies the traditional rule with respect to local remedies available either to the claimant state or to the natural or juridical entities represented by the state under authority granted by Article VIII.

As noted above, as an alternative to diplomatic claims procedures, Article XI(2) preserves the right of a state or the natural or juridical persons it represents to pursue administrative or judicial remedies available under the law of the launching state. Thus, Paragraph 2 enables the injured party to proceed directly against the party directly responsible for the injury, potentially including parts manufacturers and system operators. Depending on the law of the launching state, relief may also be available against the government of the launching state. However, recovery under this direct approach is likely to be limited, first, to the damage actually caused by government officers and employees, and second, by the problems inherent in judicial and administrative actions between sovereign and non-sovereign parties.

A second problem posed by Article XI(2) is that as a practical matter the decision to pursue a remedy under Paragraph 2 is likely to amount to waiver of a claim through diplomatic channels, since the second sentence of Paragraph 2 denies a claimant state the right to present through diplomatic channels a demand for compensation which relates to the same damage or injury which serves as the basis for judicial or administrative action under the law of the launching state. That provision raises two questions. The prohibition on simultaneous pursuit of parallel remedies combined with the consideration that the time normally required to litigate a substantial claim is likely to exceed one year would probably prevent presentation of a subsequent claim through diplomatic channels. Hence, if the statute of limitations for judicial or administrative actions exceeds one year, the injured party should consider delaying initiation of such actions pending determination of diplomatic claims. The latter possibility raises the questions, first, whether the judicial or administrative claim would be barred by res judicata or related principles, and second, whether the time limit for presentation of a claim established in Article X applies to judicial and administrative actions as well as to diplomatic claims. Although the language of Article X does not directly answer the latter question, the choice of words and Article X's relationship to Articles VIII and IX suggests that its impact is limited to diplimatic claims.

The measure of compensation to be paid to the claimant state is to be determined under Article XII

> in accordance with international law and the principles of justice and equity in order to provide such reparation . . . as will restore the person, natural or juridical, State or international organization on whose behalf the claim is presented to the condition which could have existed if the damage had not occurred.

From the perspective of space industrialists, the standard is unsatisfactory, due to its vagueness. Particularly problematic is the question of availability of interest from the time the damage occurred, lost profits and the costs of pursuing the claim. Article XII is supplemented by Article XIII which requires the launching state to pay any compensation due in the currency of the claimant state, unless the latter requests payment in the currency of the launching state, or unless the two states agree on some other form of compensation.

Articles XIV-XX provide for the establishment of a claims commission to settle claims which are presented but are not resolved through diplomatic procedures. In general these procedures do not directly affect the interests of entities contemplating industrialization of outer space. Nonetheless, three provisions should be noted. First, Article XIV requires the claimant and launching states to form a claims commission if a claim presented through diplomatic channels in accordance with the provisions of Article IX is not resolved within one year from the date the claim is presented. Second, the claims commission is authorized under Article XVIII to determine the merits of the claimant to fix the amount of compensation, if any, to be paid. Finally, Article XIX(2) provides:

> The decision of the Commission shall be final and binding if the parties have so agreed: otherwise the Commission shall render a final and recommendatory award, which the parties shall consider in good faith. The Commission shall state the reasons for its decision or award.

The fact that decisions of the commission are binding only if the states forming the commission so agree further weakens the protections offered by the convention to potential space entrepreneurs.

III. INTERNATIONAL TELECOMMUNICATION CONVENTION AND ITU RADIO REGULATIONS

The third major international instrument which is likely to influence industrial development in outer space is the International Telecommunication Convention[1] and the Radio Regulations promulgated by the International Telecommunication Union (ITU) under authority granted in the convention. The principles embodied in the Convention and the Radio Regulations are likely to be most important for space industrial installations which require utilization of the geostationary orbit.[2]

As suggested above,[3] Articles I, II and IX of the Outer Space Treaty establish general principles governing the utilization of the geostationary orbit for all purposes, including space industrialization. However, to date, international debate regarding the practical application of those provisions to the task of managing the geostationary orbit has occurred primarily at the World Administrative Radio Conferences convened by the International Telecommunication Union for the purpose of regulating global telecommunications activity and accommodating conflicting uses of the electromagnetic spectrum. During the past fifteen years the ITU has also developed an interest in the management of the geostationary orbit.

That interest is based both on the special characteristics of the orbit which make it particularly valuable for communications satellite applications and on the character of the geostationary orbit as a limited natural resource. Some experts argue that if mutual interference is to be avoided, the number of satellites in geostationary orbit must be limited to 180.[4] Others contend that the spacing of satellites could be diminished leaving only the necessary safety margin to ensure avoidance of collision, with the result that the capacity of the orbit could be increased to nearly 1800 satellites.[5] However, in order to ensure avoidance of mutual interference under the present state of communications satellite technology, the spacing must be increased beyond the minimum necessary to prevent collision. Thus, although the maximum capacity is dependent on a number of technical variables, including frequency staggering, signal polarization, signal format, location of earth stations, and transmission power, and hence cannot be precisely calculated, the geostationary orbit must be considered a limited resource.[6]

The 1959 ITU Radio Regulations which govern the use of the electromagnetic spectrum have been periodically revised to respond to developments in satellite communications. In 1963 the ITU convened the Extraordinary Administrative Radio Conference in Geneva to allocate frequencies for use by satellites. Although the Radio Regulations were partially revised,[7] the conference did not alter the historical practice of permitting individual states to assign transmission frequencies unilaterally.[8] Thus, the traditional "first come, first served" approach was extended into the realm of satellite communication where it applies both to the allocation frequencies and to occupation of orbital "parking slots" by communications satellites.[9] Since that approach gives an obvious advantage to those technologically advanced states which are presently capable of establishing geostationary satellite systems, less developed states began to exert pressure to preserve future interests in use of the orbit against saturation by more developed countries.[10]

During the following eight years, utilization of the orbit grew dramatically, causing increased concern among non-space powers. Against this background, the ITU convened the 1971 World Administrative Radio Conference for Space Telecommunications (WARC-ST) in Geneva. In opposition to proposals that the ITU should allocate not only frequencies but orbital slots as well, the United States argued that regulation of the orbit would inhibit its development as a natural resource.[11] The strength of the opposition and other complications resulted in the general preservation of the status quo.[12] Nonetheless, some progress was made toward the accommodation of the conflicting interests of states at various stages of economic and technological development. Article 9A of the Radio Regulations was revised to establish a mechanism for coordinating use of the geostationary orbit.[13] Section I requires a government which intends to establish a satellite system to convey to the International Frequency Registration Board (IFRB), the entity responsible for management of the international use of the electromagnetic spectrum,[14] within five years prior to commencement of service, information defined in Appendix 1B of the Radio Regulations relating to the characteristics of the system's satellites and earth stations, including orbital information. In particular with respect to geostationary satellites, Section II requires any government considering the use of the orbit to coordinate the planned use -- prior to notification of the IFRB under Section I on commencement of service -- with any other government which has registered an assignment in the same band with the IFRB or which is engaged in or has completed coordination procedures under this section. To facilitate coordination the former is to supply the information defined in Appendix 1A of the Regulations. The purpose of this coordination procedure is to promote resolution of potential conflicts prior to commencement of system construction.

Another element of the effort of delegates to the WARC-ST conference to resolve conflicts regarding management of the orbit is embodied in Resolution Spa 2-1, which reflected the concern of non-space powers regarding the management of the orbit. In part the resolution provides:

> The World Administrative Radio Conference for Space Telecommunications (Geneva, 1971),
>
> *considering*
>
> that all countries have equal rights in the use of both the radio frequencies allocated to various space radiocommunication services and the geostationary satellite orbit for these services;
>
> *taking into account*
>
> that the radio frequency spectrum and the geostationary satellite orbit are limited natural resources and should be most effectively and economically used;
>
> *having in mind*
>
> that the use of the allocated frequency bands and fixed positions in the geostationary satellite orbit by individual countries or groups of countries can start at various dates depending on requirements and readiness of technical facilities of countries;

> *resolves*
> 1. that the registration with the ITU of frequency assignments for space radiocommunication services and their use should not provide any permanent priority for any individual country or groups of countries and should not create an obstacle to the establishment of space systems by other countries . . . .

The linkage between the revised version of Article 9A and Resolution Spa 2-1 is embodied in Resolution Spa 2-2 which reiterated the importance of achieving the best possible use of the geostationary orbit and the frequency bands assigned to the broadcasting satellite service, and which called upon participating governments to establish and operate satellite broadcasting systems in accordance with plans established by general and regional conferences in which affected states are entitled to participate.[15] Although not binding on the parties to the International Telecommunication Convention,[16] the resolutions expressed a broadening consensus among participating delegations and emphasized the fact that the Radio Regulation does not provide permanent protection to spectrum and orbital assignments for space broadcasting services.[17] However, the resolutions did not allay the concern of non-space powers that present space activities will saturate the most desirable segments of the orbital arc.

The third phase of the ITU's consideration of the problem of allocating the geostationary orbit among potentially conflicting uses occurred at the Plenipotentiary Conference of the ITU which was held in September and October 1973 in Torremolinos. The basic purpose of the conference was to evaluate and, if necessary, revise the ITU's fundamental structure and functions.

In addition, the question of orbital slot allocation was included in the agenda.[18] In that context the Israeli delegation proposed to modify the International Telecommunication Convention to authorize ITU allocation of both the frequency spectrum and geostationary orbital slots as a means of ensuring equitable access by all parties.[19] Although the Israeli proposal did not receive the support required for adoption, the Plenipotentiary Conference amended the listing of the duties to be performed by the IFRB contained in Article 10 of the Convention to add relatively undefined responsibilities relating to the geostationary orbit. In revised form Article 10(3) provides:

> The essential duties of the International Frequency Registration Board shall be:
>
> a) to effect an orderly recording of frequency assignments made by the different countries so as to establish, in accordance with the procedure provided for in the Radio Regulations and in accordance with any decision which may be taken by competent conferences of the Union, the date, purpose and technical characteristics of each of these assignments, with a view to ensuring formal international recognition thereof.
>
> aa) to effect, in the same conditions and for the same purpose, an orderly recording of the positions assigned by countries to geostationary satellites;
>
> b) to furnish advice to Members with a view to the operation of the maximum practicable number of radio channels in those portions of the spectrum where harmful interference may occur, and with a view to the equitable, effective and economical use of the geostationary satellite orbit;
>
> c) to perform any additional duties, concerned with the assignment and utilization of frequencies and with the utilization of the geostationary satellite orbit, in accordance with the procedures provided for in the Radio Regulations, and as prescribed by a competent conference of the Union, or by the Administrative Council with the consent of a majority of the Members of the Union, in preparation for or in pursuance of the decisions of such a conference . . . . (emphasis added)

In essence, the IFRB was instructed to record use of orbital slots on the same basis as frequencies for space services.

Although the revised version of Article 10 authorized recording of orbital use, the basic "first come, first served" approach was not altered. However, in order to preserve the interests of non-space powers, the Plenipotentiary Conference also revised Article 33 to provide:

> Rational Use of the Radio Frequency Spectrum and of the Geostationary Satellite Orbit
>
> In using frequency bands for radio space services Members shall bear in mind that radio frequencies and the geostationary satellite orbit are limited natural resources, that they must be used efficiently and economically so that countries or groups of countries may have equitable access to both in conformity with the provisions of the Radio Regulations according to their needs and the technical facilities at their disposal.[20]

Read in combination, the revised version of Articles 10 and 33, which became effective January 1, 1975, lead to a series of conclusions regarding the status of management of the geostationary orbit:

1. Countries are entitled to utilize the geostationary orbit and to record such use with the IFRB:
2. At least during the period of active use of an orbital slot, the system operator is protected against harmful interference from subsequently established systems by the coordination requirements of Article 9A;
3. The system operator is not entitled to permanent utilization of any particular orbital slot; and

4. Governments operating geostationary satellites are required to conduct their operations in such a way as to permit equitable areas to orbital slots by other governments subsequently establishing communications systems based on the use of geostationary satellites.

At the 1977 World Administrative Radio Conference for the planning of the broadcasting-satellite service in the 12 GHz band (WARC-BS), principles to govern the management of the geostationary orbit were discussed. During the debates,[21] Columbia and other equatorial states raised the question of national sovereignty over the geostationary orbit. At the 1975 session of the First Committee of the General Assembly, Colombia had asserted that the geostationary orbit is a natural resource over which equatorial states are entitled to exercise sovereign rights in relation to the segments of the arc located over their respective territories.[22] Similar contentions had been incorporated in the Bogota Declaration of December 3, 1976.[23] The states which supported that document raised the question at WARC-BS and stated their opposition to allocation of orbital slots in an effort to promote international recognition of national jurisdictional control. Recognition of that approach would permit the equatorial states to control access to the orbit, most likely on a licensing basis. However, conflicts with the "free use" principle of Article I(2) and the Article II prohibition against appropriation as well as the low level of support from non-equatorial states suggest that the establishment of an international consensus on this approach is unlikely.

The remaining delegations divided their support between development of an *a priori* plan and evolutionary planning for orbital slot and frequency allocation. Under the first approach, a comprehensive plan covering all aspects of the allocation question would be developed in an attempt to accommodate to the maximum possible extent the whole set of needs foreseen by the period covered by the plan.[24] In contrast, under evolutionary planning, system design and deployment would be undertaken within limits imposed by a series of general sharing principles and would be based as prior consultations with other governments whose existing systems could be affected by the establishment of new systems. Under that approach, no advance assignments of orbital slots frequencies and signal polarizations are made, permitting actual use to benefit from advancing technology.[25]

The *a priori* approach enjoyed substantial support from a significant number of non-equatorial states in Regions I and III. The United States led another bloc of states including Canada and Brazil which opposed *a priori* planning supporting instead various forms of evolutionary allocation for Region II. When the WARC-BS ended, no *a priori* plan was approved for Region II, but a conference of Region II countries, including North and South America and the Caribbean states, was scheduled for 1982, at which a "detailed plan" is to be considered.[26] Thus, the conference did not significantly alter the existing regime with respect to use of the geostationary orbit by the United States, Canada and Latin America. However, technological advances are likely to result in increased pressure to preserve rights of access for states which do not yet possess the capability to operate satellite systems.

In June and July 1976, the Administrative Council of the ITU met in Geneva to determine, among other things, the agenda for the 1979 World Administrative Radio Conference. In its present form,[27] the agenda calls for the review and, if necessary, revision of Articles 9 and 9A relating to the coordination, notification and recording of frequency assignments.[28] As noted above, Article 9A establishes procedures for coordinating use of the geostationary orbit.[29]

In the context of discussions of Article 9A, the issue of allocating orbital slots is likely to be raised. Participating delegations are expected to align themselves along the lines drawn at the WARC-BS. Equatorial states will continue to press their claims that the geostationary orbit is a natural resource subject to the sovereign control of individual countries which lie along the equator. The non-equatorial developing countries and those which are considered developed but which do not yet possess the capability to operate sophisticated satellite systems can be expected to press for adoption of a comprehensive frequency and orbital slot allocation plan which would ensure future access to segments of the geostationary orbit suitable for national or regional use. The United States and other space powers are likely to continue their support of evolutionary planning in order both to ensure maximum use of the orbit and to incorporate technological advances into the allocation scheme as rapidly as they occur.

The debate will be given a sense of urgency by intervening communications satellite experimentation and the evolution of planning for operational domestic, regional and global satellite networks. Canadian and American experimentation using the ATS-6 and CTS systems will focus on applications of geostationary, high-power broadband satellites transmissions in conjunction with small terrestrial receiving terminals.[30] In addition, experimental activities by the European Space Agency (ESA) and the Japanese National Space Development Agency (NSDA) are expected to demonstrate the utility of new applications.[31]

These experimental activities will provide the basis for expanded operational use of geostationary communications satellites. Significant expansion of the Intelsat network and deployment of new Intelsat V satellites are projected.[32] On the regional level, the Arab League's Telecommunications Union is considering establishing a system based on geostationary satellites for the provision of broadcast and telephone services to each member country.[33] Expanded domestic systems are either under development or in the planning phase in the United States, Canada, Indonesia, Iran and Japan. In addition, a number of countries, including Algeria, Zaire, Brazil, Nigeria and Norway have leased or are considering leasing transponders from Intelsat for dedicated use in domestic systems.[34]

Increases in existing and planned use of the geostationary orbit for communications and other purposes will provide impetus for the 1979 WARC debate regarding allocation of the geostationary orbit. Because of the key role played in the existing law of outer space by the "free use" principle of Article I(2) and the non-appropriation principle of Article II, and in light of the potential economic and social value of the proposed satellite applications based on the use of the geostationary orbit, the claims of equatorial states to sovereign control over large segments of the orbit are unlikely to receive broad international recognition. Thus, the main struggle is likely to take place between comprehensive advance allocation of frequency and orbital slots and allocation according to actual use, taking into account existing systems and advancing technology.

Current positions and trends of discussion indicate that although substantial discussion of the problem will occur at the 1979 WARC, no definitive solution will be reached, because of the strength of the competing interests involved. Proposals for both a priori and evolutionary planning are likely to be referred for consideration to regional conferences. After consideration there, the resulting recommendations will probably be re-examined at a general WARC in the mid-1980s. Debates at the 1979 WARC and subsequent conferences are likely to reveal a trend toward the assignment within each region of orbital segments dedicated to individual communications services. Within each segment, each country would be assured equitable access to orbital slots, but no specific frequency or orbital slot allocations would be made in advance of actual use. Despite a trend toward that approach, complicating factors including non-communications applications such as satellite power generation are likely to delay establishment of an effective compromise among competing interests.

Thus, the impact of the 1979 WARC on the development and establishment of satellite power systems is likely to center on identification, first, of the problems of coordinating potential uses of the geostationary orbit to avoid mutual harmful interference, and second, of the competing interests of equatorial, developing and developed countries in the use of the orbit. In particular, since satellite power systems are not likely to be operational prior to 1995 and therefore are dependent on long-term orbital management activities, the progress projected for the 1979 WARC is likely to emphasize the importance of preliminary planning and evaluation of future orbital requirements for satellite power systems in order to ensure that future conferences take into account both the need to establish such systems and, if established, their projected orbital requirements.

PART III

The treaties and conventions discussed in Part III provide the general legal framework within which the industrialization of outer space is likely to evolve. As technological advances make establishment of experimental and operational systems imminent, various members of the international community will initiate efforts to elaborate the general instruments discussed above by establishing more specific guidelines to govern particular activities. Thus, for example, planning and experimentation relating to direct broadcast and earth resources satellites have promoted extensive consideration of relevant technical, organizational and legal guidelines by the United Nations Committee on the Peaceful Uses of Outer Space (CPUOS) and its subcommittees. To the extent that the concept of space industrialization encompasses the direct television broadcasting via satellite, remote sensing and closely related activities, the CPUOS debates provide a basis for predictions regarding the structure of international space law at the time such systems become fully operational. The CPUOS debates also indicate trends which are likely to influence future negotiations relating to uses of outer space which are not yet under consideration in CPUOS, including satellite power systems and space manufacturing.

In addition to trends indicated by CPUOS activities, other evidence regarding the future of international space law can be derived from developments in other areas of international law. One example is the analogy which can be drawn to the positions taken by various delegations on legal and institutional issues at the present series of United Nations Conferences on the Law of the Sea as reflected in the negotiating texts. Another example is the evolving concept of "the common heritage of mankind" which has received some measure of support in negotiations relating to the management of both the seas and outer space. Further guidance on questions relating to potential organizational configurations for entities engaged in space industrialization can be derived from current trends as evidenced by the practice of Intelsat, Inmarsat and Aerosat.

The purpose of Part III is to examine the most important of these trends:

1. direct broadcast satellites;
2. earth resources satellites; and
3. the draft moon treatv.

I. IMPLICATIONS OF THE COPUOS DEBATES ON DIRECT SATELLITE BROADCASTING FOR SPACE INDUSTRIALIZATION

NASA research and development activities utilizing the ATS and CTS systems have demonstrated the technical feasibility of direct broadcast satellites capable of transmitting program carrying signals directly to small-scale ground receivers, bypassing the complex terrestrial redistribution networks presently employed by existing systems.[1]

Direct broadcasting from satellites promises a number of benefits, including more efficient and extensive program dissemination on a national level both for educational and entertainment purposes and for increased interchange of ideas and information between cultures. Perhaps the most important of these is the potential for improving the quality of education. In all of the developing countries, and even in some of those considered developed, a shortage of well-qualified teachers has hindered national development, setting in motion a search for means to overcome the shortage. Educational television has been used successfully in many parts of the world to distribute over a wide area resources previously available only in isolated special teaching facilities. In a large number of countries, however, the absence of a well-developed, in-place terrestrial distribution system for educational programming, compounded by the difficulty of installation due to high costs, difficult terrain or a widely dispersed population, has prevented full realization of television's educational potential. Direct satellite broadcasting technology is capable of overcoming these barriers, provided that certain economic and technical obstacles are overcome.

Along with its promise of increased interchange among peoples, direct broadcasting has also created concern among potential "receiving states" that the new technology will be exploited for purposes of propaganda or for cultural or economic imperialism. As early as 1963 that concern generated demands that a restrictive international legal regime be imposed on the use of direct broadcasting to prevent potential misuses. The significant initiatives in that regard have centered in the United Nations, taking place in a variety of agencies, including CPUOS, the ITU and UNESCO.

A. Main Positions

During the United Nations debate, three main positions have emerged. After a short initial period at the opposite pole, the Soviet Union has led Argentina, Brazil, Egypt, France and the Eastern European bloc in expressing concern over the potential for satellite transmission of politically subversive or culturally disruptive broadcasts across national boundaries without the prior consent of the receiving state. A number of less developed states have echoed the Soviet concern over propaganda. Morocco, Iran, Sierra Leone, and India, among other Third World states, have been especially concerned about cultural imperialism and the possibility that commercial advertising by the industrial powers would disrupt the social fabric of developing nations. Some Third World nations have suggested that any television program displaying consumer-oriented societies in a favorable light would create a demand for consumer goods among their own citizens which could delay or perhaps even thwart national plans for social and economic development.[2] The key elements upon which these states would ultimately base an international institutional response are the principles of national sovereignty and the need to protect established cultures against intrusion from abroad.

Opposition to the restrictive regulatory approach taken by the Soviet Union has been led by the United States, which has argued, first, that any regulation was premature, since no one could determine with any degree of certainty either the configuration of future direct broadcast systems or the nature of the political, economic and legal problems likely to arise when such systems finally become operational, and second, that an excessively restrictive policy could stifle the initiatives necessary to develop and implement direct broadcast technology. The third tenet of the United States' position has been the contention that a regime of prior consent and program control would violate both the First Amendment and the principle of the free flow of information contained in the Declaration of Human Rights, and would, therefore, be unacceptable as a matter of constitutional policy.

Sweden and Canada have taken an intermediate position, recognizing the need to incorporate both the free flow of information and the protection of national sovereignty and cultural diversity into any viable regulatory scheme. To achieve that goal, the two states have advocated a regime based on international cooperation expressed in a prior agreement between the broadcasting and receiving states. Under the Swedish-Canadian proposal, program content would be determined by the bilateral prior consent agreement rather than by a global agreement as proposed by the Soviets.

The current series of CPUOS negotiations began in 1969 when the Working Group on Direct Broadcast Satellites was convened in New York pursuant to General Assembly Resolution 2453 B (XXIII).[3] After the Working Group held five sessions, the main debate regarding appropriate governing principles shifted to the Legal Sub-Committee in 1974, where some progress has been made toward the establishment of an international consensus. The basic foundations of the debate were embodied in proposals submitted by the Soviet Union, the United States and jointly by Sweden and Canada.

1. *The 1972 Soviet Draft Convention*

Concerned about the American progress with communications satellite technology, the Soviet Union unexpectedly introduced its restrictive Draft Convention on Principles Governing the Use by States of Artificial Earth Satellites for Direct Television Broadcasting to the General Assembly on 8 August 1972.[4] In a letter addressed to the Secretary-General, Soviet Foreign Minister Andrei Gromyko requested that the twenty-seventh session of the General Assembly examine the feasibility of an international agreement for satellite broadcast regulation and that the Soviet proposal be included on the agenda.[5] The Soviet Union intended its draft to provide the foundation for a universally binding treaty approved by the CPUOS Legal Sub-Committee.

As submitted, the Soviet draft contained nearly all of the restrictive principles proposed during the previous meetings of the Working Group, including a strict provision permitting direct satellite broadcasting to foreign states "only with the express consent of the latter."[6] Article IV provided that any party to the proposed convention would undertake to exclude from programming transmitted via satellite "any material publicizing ideas of war, militarism, nazism, national and racial hatred and enmity between peoples, as well as material which is immoral or instigating in nature or is otherwise aimed at interfering in the domestic affairs or foreign policy of other states." Article VI elaborated the general statements of Article IV, listing specific categories of satellite broadcasting which would be illegal:

> (a) Broadcasts detrimental to the maintenance of international peace and security;
>
> (b) Broadcasts representing interference in intra-state conflicts of any kind;
>
> (c) Broadcasts involving an encroachment on fundamental human rights, on the dignity and worth of the human person and on the fundamental freedoms for all without distinction as to race, sex, language or religion;

(d) Broadcasts propagandizing violence, horrors, pornography, and the use of narcotics;

(e) Broadcasts undermining the foundations of the local civilization, culture, way of life, traditions or language;

(f) Broadcasts which misinform the public in these or other matters.

The ban on specific categories of program content was supported by Article XII, which would have denied any party to the convention the right to enter into any subsequent international agreement which conflicted with the convention. Thus, the proposed program content limitations were apparently intended to apply even if the broadcasting and receiving states had agreed to waive one or more of the limitations. Consequently, under the Soviet draft, any third state which considered the programming exchanged between the broadcasting and receiving state--even if pursuant to an agreement between the two--to fall within the proscribed categories, could invoke the remedial procedures foreseen in the Soviet draft, even if there were no possibility that the third state's citizens would receive the allegedly objectionable transmissions. In addition, the proposal also forbade advertising, except "on the basis of specific agreements specially concluded between those states concerned."[7]

The foundation for the remedial process was laid by Article VI, which imposed international liability of states against a broadcasting state where programming contained proscribed materials. Article VII extended the liability of the broadcasting state to include any act of illegal broadcasting by one of its nationals, whether or not the broadcast was actually transmitted by a government agency. The imposition of international liability presumably made available to the objecting state all of the normal remedial procedures provided by international law. Article IX, however, also permitted the target state to "employ the means at its disposal" to counteract the illegal irradiation of its territory by a foreign state.[8] The convention did not state explicitly whether retaliatory military action against the satellite would be permissible in such cases. However, that interpretation was given credence by language contained in Foreign Minister Gromyko's letter conveying the draft convention to the Secretary-General:

> States may utilize the means at their disposal to counteract illegal direct broadcasting of which they are the object, not only in their own territory but also in outer space and other areas beyond the limits of national jurisdiction of any state.[9]

Gromyko's statement leaves open a number of undesirable responses by the target state, including the destruction of the satellite in space. Eventually, however, the Soviets indicated that only "lawful" measures would be authorized under the convention.[10]

The Secretary-General referred the Soviet draft to the Committee on the Peaceful Uses of Outer Space, which in turn approved consideration of direct broadcast issues by the Working Group at its fourth session.[11]

At the fifth session of the Working Group, the Soviet Union also took a slightly moderated position, substituting a draft declaration of principles for the draft convention.[12] The substantive provisions were essentially identical to those of the 1972 draft convention, with two exceptions. The first exception was the draft declaration's omission of the listing of prescribed categories of program content in Article VI of the draft convention.[13] Although the specific listing is omitted, the general prescriptions of programs promoting militarism, racial hatred and cultural subversion contained in Article IV of the convention are retained in Article IV of the draft declaration, leaving the scope or effect of the limits on program content substantially unaffected.

A second difference between the two drafts relates to the issue of spillover. Under Article VIII(2) of the 1972 draft convention, any state believing itself subjected to unintentional radiation would have been entitled only to request consultations with the broadcasting state. The draft declaration would have authorized the offended state to compel immediate consultations regarding program content if the unintentional spillover were receivable in its territory by ordinary receivers or receivers augmented by simple devices.[14] Both drafts would have proscribed any intentional broadcast unless authorized by prior agreement between the broadcasting and receiving states.[15]

The final difference between the two Soviet drafts is found in the remedial provisions. Article IX(1) of the 1972 draft convention would have permitted any party to the convention to:

> employ the means at its disposal to counteract illegal television broadcasting of which it is the object, not only in its own territory but also in outer space and other areas beyond the limits of the national jurisdiction of any State,

leaving open the possibility that an offended state might consider itself entitled to destroy the satellite relaying allegedly unlawful programming.[16] The counterpart to Article IX(1) in the draft declaration limits the response of the complainant state to those "measures which are recognized as legal under international law.[17]

Despite the near identity between the operative provisions of the 1972 draft convention and the 1974 draft declaration, the former represents a moderation of the Soviet position. By accepting a non-binding declaration, rather than a treaty, as the appropriate mode for expressing an international consensus, the Soviets moved toward compromise with the American and Swedish-Canadian positions.

2. *The Swedish-Canadian Draft Principles*

Also considered at the fourth session of the Working Group in 1973 was a draft declaration submitted jointly by the Swedish and Canadian delegations. Officially entitled The Draft Principles Governing Direct Television Broadcasting by Satellite,[18] the Swedish-Canadian proposal attempted to reconcile the free flow of information with national sovereignty through the application of the basic principles of cooperation and participation. Like the Soviet draft convention, the joint Swedish-Canadian proposal would have required the broadcaster to secure the consent of the recipient state:

> Direct television broadcasting by satellite to any foreign State shall be undertaken only with the consent of that State. The consenting State shall have the right to participate in activities which involve coverage of territory under its jurisdiction and control. This participation shall be governed by appropriate international arrangements between the States involved . . . .[19]

The draft declaration did not, however, include an explicit program code. Instead, Article VIII would have mandated participation of the recipient state in "the scheduling, content, production and exchange of programmes and all other aspects, including if appropriate, the training of technical and programme personnel."[20] The combination of prior consent and participation provisions would have nullified the potential for offensive program content, while permitting the participatory states to tailor programming to their respective needs. Although the prior consent provision was comparable to that proposed in the Soviet draft, the Swedish-Canadian draft would have permitted interested states to consent to any type of programming, while the Soviets advocated the establishment of prohibitions against specific categories of content.[21]

The Swedish-Canadian draft declaration also would have distinguished between technically unavoidable spillover and the intentional transmission of television signals to a foreign country. While the prior consent clause would not have operated in the case of unavoidable spillover, the draft declaration specified that the consent and participation provisions were to be applicable in situations:

> (a) where coverage of the territory of a foreign State entails radiation of the satellite signal beyond the limits considered technically unavoidable under the Radio Regulations of the International Telecommunication Union; or
>
> (b) where notwithstanding the technical unavoidability of spillover to the territory of a foreign State, the satellite broadcast is aimed specifically at an audience in that State within the area of spillover.[22]

If any state concluded that another was violating the principles set forth above, the joint document would have authorized the former to call upon the latter to enter into consultations regarding the alleged violations. If the consultations did not reach a mutually acceptable settlement, the aggrieved state would have been entitled to seek a settlement through the established procedures for the resolution of disputes "such as conciliation, mediation, arbitration or judicial settlement."[23]

The Swedish-Canadian draft appears to be a useful compromise between the Soviet draft convention and the arguments presented orally by the American delegation. The proposal contained an explicit prior consent provision, similar to that sought by the Soviets, but it omitted the controls on program content so vehemently opposed by the American delegation. Nonetheless, the ommission was potentially compatible with the Soviet position, since the shared control of specific programming could serve as an effective substitute. The joint proposal would also have assured American broadcasters that they would not be forbidden to transmit commercial programming to other nations on the basis of objections based on content, provided they were able to persuade the receiving state to consent to receive direct broadcasting. In addition, a state irradiated by spillover resulting from consented transmission between two other states could not interfere with the transmissions on the ground that it had not also consented, if the spillover were technically unavoidable and not specifically directed at the complaining state. Finally, the fact that the document did not authorize censorship or contain a list of proscribed programs could have eased the American constitutional objections to international broadcast regulation.

3. *The United States Draft Principles*

During the first four sessions of the Working Group, the United States consistently argued that any international declaration or treaty on direct broadcasting would impede development and operational implementation of the technology. However, in response to the Soviet and Swedish-Canadian initiatives, the United States delegation submitted its own draft declaration of principles to the fifth session of the Working Group. Framed in general terms, the American Draft Principles on Direct Broadcast Satellites[24] did not attempt to enumerate illegal broadcast applications. In contrast to the Soviet document, the American proposal took a positive approach, encouraging rather than limiting the use of direct broadcast satellites. The draft recognized the need for direct broadcasting to develop within the limits imposed by the ITU technical parameters and procedures, as well as by international law, including the United Nations Charter and the Outer Space Treaty.[25] In its proposal the United States also included the principle that direct broadcasting should be carried out in a manner both compatible with the maintenance of international peace and sensitive to the differences among cultures.[26] Within that framework the American delegation proposed that the evolving technology be applied so as to "encourage and expand the free and open exchange of information and ideas."[27] Implementation of the fundamental principle of the free flow of information was to be achieved by promoting access of every state to both transmitting and receiving facilities insofar as technical obstacles could be overcome.[28] The organizational and programming barriers were to be overcome through cooperative efforts of international organizations and regional broadcasting associations,[29] with any disputes to be resolved by established procedures.[30] Finally, the draft principles introduced by the United States delegation called upon the United Nations and its member states to "review the questions of the use of satellites for international direct television broadcasting if practical experience indicates the need for such a review.[31]

From the beginning of the direct broadcast debate, the basic tenets of the American position had been the free flow of information, deferral of regulation until concrete problems have arisen, and application of the evolving technology through regional cooperation. Thus, in one sense, the proposed principles simply formalized the previously established position. Nonetheless, the American draft represented an important step toward compromise. Until the Working Group's fifth session, the United States had opposed any attempt to establish limitations, whether binding or not, on direct broadcasting. By introducing its own set of draft principles, the United States accepted the proposition that the establishment of such non-binding principles would facilitate the development of the technology. The American proposal also recognized for the first time the need to include a provision for broad access in order to ensure the two-way flow envisioned in the principle of free flow of information. Although conditioned upon the ability to overcome unspecified "practical difficulites," the shared access principle represented another step toward resolution of the direct broadcast controversy.

B. Present Status of the Direct Broadcast Debate

Since 1974 the CPUOS Legal Sub-Committee has made some progress toward a consensus on direct broadcast issues. The following subsections are intended to describe the current status of the debates on specific key issues.

1. Purposes and Objectives

At the final session of the Working Group in 1974, the delegations agreed that direct broadcasting should have as its goals the promotion of international peace, the facilitation of global economic and social development and the furtherance of intercultural understanding.[32] The report concluded that all direct broadcasting activities should be conducted exclusively in a manner compatible with those goals.[33] However, at the fourteenth session of the Legal Sub-Committee, one group of delegates argued that that policy should be made mandatory, while others contended that the principle in question should remain a non-obligatory statement of a general policy.[34] During the fifteenth session, the delegations agreed on the latter approach.[35]

2. Applicability of International Law

The report of the fourteenth session of the subcommittee recognized that the United Nations Charter, the Outer Space Treaty, and the International Telecommunication Convention with its Radio Regulations had established general limits within which direct broadcasting would have to evolve.[36] Left unresolved, however, was the issue whether the draft principle regarding the applicability of international law should state that direct broadcasting "should be" conducted in accordance with generally recognized rules or whether such a provision should impose on states the obligation to ensure the compliance of activities within their jurisdiction.[37] In addition, disagreement remained relating to the inclusion among the principles to be applied of the Universal Declaration of Human Rights, the International Covenant on Civil and Political Rights and the Declaration on Principles of International Law Concerning Friendly Relations and Cooperation Among States.[38]

Article III of the 1967 Outer Space Treaty appears to resolve the first question by obligating states who are parties to the treaty to conduct activities in outer space in accordance with international law.[39] Consequently, the obligation of states to comply with international law would not be diminished by omission of an express statement of the obligation. Thus, the decision of the subcommittee at its fifteenth session to endorse non-obligatory language does not seriously limit the legal impact of the draft declaration ultimately approved by CPUOS.[40]

Although the inclusion of general references to the Universal Declaration of Human Rights, the International Covenant on Civil and Political Rights, and the Declaration of Principles of International Law Concerning Friendly Relations and Cooperation Among States could be justified as an additional step toward the establishment both of a liberal regime for direct broadcasting which would facilitate educational application and of customary rules regarding an international obligation to protect human rights, the practicalities of international negotiation in the present case seem to indicate that reference will be made only to those principles particularly relevant to the direct broadcast controversy, namely sovereignty, non-intervention, and the free flow of information. In order to facilitate establishment of a consensus, the subcommittee agreed in 1976 to substitute the phrase "the relevant provisions of . . . international instruments relating to friendly relations and co-operation among States and to human rights" in place of reference to specific instruments as previously proposed.[41]

3. *Rights and Benefits*

At the 1974 session of the Working Group, the participating delegations agreed that all states have an equal right to conduct or authorize direct broadcasting, and that all states are entitled to share in the benefits of the new technology, regardless of their degree of economic or scientific development.[42] The sharing of benefits thus foreseen was to include increasing opportunities for access to direct broadcast systems, based on specific agreements between the states concerned.[43] The basic consensus was not disturbed at the fourteenth session of the Legal Sub-Committee. Two sub-issues were, however, left unresolved.[44] First, some delegations advocated inclusion of a provision limiting direct broadcast activities to either governmental agencies or entities under government supervision. The inclusion of such a provision would be important to the imposition of the international liability of states, and would therefore be an essential part of any regime designed to impose enforceable restrictions on program content. In all of its proposals, the Soviet Union has consistently sought to restrict direct broadcast activities to those entities controlled by their respective governments.[45] The United States has resisted such attempts in order to preserve the use of direct broadcast satellites for commercial programming. A second sub-issue arose regarding whether the right of equitable sharing in the benefits of direct broadcasting should be stated in obligatory or normative terms.[46] The subcommittee reached agreement at its 1976 session based on normative rather than obligatory language and on the deletion of express references to both supervision by governments and activities of individuals in outer space.[47]

4. International Cooperation

Strong recognition was given to the principle of international cooperation in the report of the fifth Working Group which described corporations as a "touchstone for the development and use of direct television broadcasting by satellite," and called upon states and international organizations, both governmental and non-governmental, to make every effort to enhance the capabilities of interested states to take advantage of direct broadcast technology.[48] Disagreement surfaced, however, in Legal Sub-Committee discussions regarding the application of the principle. Some delegations argued that direct broadcasting should be "based on" international cooperation, while others advocated a regime in which direct broadcasting would "encourage" international cooperation.[49] The former position was consistent with the Swedish-Canadian position that international cooperation is essential to the realization of the educational potential of direct broadcasting, and that any set of governing principles should include a general prior consent provision. The position that direct broadcasting should "encourage" international cooperation expressed optimism regarding the educational value of direct broadcasting, but did not mention -- and presumably implicitly rejected -- the principle of prior consent. A compromise was reached at the fifteenth session of the Legal Sub-Committee which provided that direct broadcasting activities "should be based upon and encourage international co-operation."[50]

5. *State Responsibility*

A consensus was also obtained by the fourteenth session of the Legal Sub-Committee on the issue of state responsibility. The delegations at the fifth Working Group had agreed that states should bear international responsibility for direct broadcast activities as described in Article VI of the Outer Space Treaty.[51] Beyond that point disagreement on the issue surfaced. Some delegations argued that a state should bear international responsibility for all activities carried out by its nationals, regardless of whether the government had any authority under its constitution and laws. Other delegations rejected that argument, contending that the advantage of such a principle would have made states internationally liable for the content of programming, a result which would have been unacceptable, especially for those states whose broadcasting entities were not subject to state control.[52]

The Legal Sub-Committee's drafting group resolved the disagreement and achieved a complete consensus regarding the question of state responsibility for direct broadcasting. Building on the foundation laid in the Outer Space Treaty, the draft principle accepted by the drafting group would impose responsibility on a state to ensure that all activities carried out by the state or under its jurisdiction are conducted in conformity with the whole set of draft principles.[53] Where direct broadcasting is carried out by an international organization, international responsibility would be borne both by the organization and by individual member states.[54] The essential elements of this agreement were not altered by the negotiations of the subcommittee's fifteenth session.[55]

6. *Duty and Right to Consult*

At the conclusion of the fourteenth session, no consensus was established on conflicting proposals regarding consultation between states with respect to direct broadcasting. The subcommittee reported two alternative proposals.[56] The first, supported mainly by potential "receiving" states, would have authorized a state which had reason to believe that its interests would be adversely affected by the direct broadcast activities of another state to request consultations with the broadcasting state. Under that approach, the broadcasting state would have been required to enter into appropriate consultations without delay. The second alternative would have provided that any state which received a request for consultation regarding the direct broadcast activities of either should agree to commence such consultations without delay. At its fifteenth session, the subcommittee was able to reach agreement on a draft principle which parallels the second alternative described above.[57]

7. *Prior Consent*

The most difficult problem in the resolution of the direct broadcast controversy is the prior consent issue. At the close of the fifth session of the Working Group, the delegations remained divided into three main factions on the issue of prior consent, with the largest group favoring a legal regime granting the receiving state the right to deny its consent. That group argued that prior consent is consistent with the recognized right of each state to regulate its own communications system, and that a prior consent regime would avoid contravention of national broadcasting legislation.[58] The same faction also noted that the international community had already adopted the principle of prior consent when it adopted Article 7, §428A of the ITU Radio Regulations at the 1971 WARC-ST Conference.[59]

The second major group maintained that a clear distinction must be drawn between direct broadcasts intentionally transmitted to a foreign state and those received there as a result of unavoidable spillover. In the first case, it was argued, prior consent should be required, because the principle of sovereignty gives each state the right to determine the form of its own political, economic and social systems, and therefore, the flow of information in its territory. Further, the inequality of opportunity to use direct broadcast technology strengthens the need for the protection which would be provided in a regime based on the concept of prior consent.[60]

The third major faction rejected the principle of prior consent altogether. These delegations argued that the right of prior consent would give the receiving state the authority to veto the transmission of any given program, thereby progressively undermining the principle of the free flow of information contrary to Article 19 of the Universal Declaration of Human Rights.[61] In addition, the imposition of a regime based on prior consent would inhibit full realization of direct broadcast technology, particularly for domestic systems, if the principle were applied to spillover.[62]

When the Legal Sub-Committee adjoined its fourteenth session, two main positions on the questions of prior consent remained. Proponents of the first position would prohibit direct broadcasts to any state unless that state had consented. If consent were given, the consenting state would have the right to participate in activities related to coverage of its territory. These consent and participation principles would not apply, however, where coverage of the foreign state resulted from technically unavoidable spillover as defined in the ITU's Radio Regulations.[63] This position appears to correspond to the principles proposed by the Swedish and Canadian delegations to the fourth session of the Working Group.[64]

The second faction rejected the principle of prior consent, preferring instead a legal regime based on an undefined foundation of participation and cooperation.[65] The sole concrete element of cooperation approved by the second faction called upon the broadcasting state to consult with any receiving state on the request of the latter; however, the principle proposed would call for such consultations only with respect to restrictions imposed by the broadcasting state.[66]

During the 1976 session, the subcommittee was unable to report any progress. The reports of the fourteenth and fifteenth sessions contain identical sets of two alternative draft principles.[67]

8. *Spillover*

On the spillover issue, two main positions remained at the end of the Working Group's fifth session. The first group argued that since some spillover would be unavoidable, international principles should be elaborated to minimize international conflict. The other faction responded that technical developments might eliminate most problems created by spillover before individual reception in spillover areas will have become possible, thus obviating the need for a legal framework to resolve spillover disputes, particularly when technical procedures are already available under the auspices of the ITU.[68]

During the fourteenth session of the subcommittee, these positions crystallized somewhat. One position would require the broadcasting state to use "all technical means available to reduce, to the maximum extent practicable, the radiation over the territory of other countries" unless a prior agreement has been reached between the broadcasting and receiving states.[69] The other position would impose no requirement, but merely states that "all reasonable means should be used to reduce to a minimum any unintended radiation of the territory of other countries.[70] The latter position is consistent with the unlimited regime advocated by the United States, while the former would be an integral part of the prior consent regime proposed in the Swedish-Canadian drafts.

Some movement on the spillover issue was evident at the 1976 session. Previous session reports had incorporated a separate draft principle covering the spillover question.[71] During the fifteenth session, the separate spillover principle was deleted, and its suostance was incorporated into the Alternative A of the proposed consent principle which would permit the receiving state to deny its consent to direct broadcasts.[72]

9. *Program Content*

Another key issue upon which the delegations were unable to establish a consensus was the question whether a set of international principles governing direct broadcasting should proscribe certain categories of program content. One group of delegations argued that any such legal regime should combine a prior consent provision with an obligation to exclude from direct broadcasts programs which would threaten international peace, or which would promote war, militarism or social hatred, or which would undermine the foundations of the local civilization in any way.[73] The listing of programs to be banned resembled those contained in both the Soviet Union's 1972 draft convention and its 1974 draft declaration of principles.[74]

The second main position was similar to that advanced by the Swedish and Canadian delegations in previous sessions. The report of the fifth Working Group noted that some delegations had espoused the view that because of political, eononomic, social and cultural differences among states, the establishment of general principles or objective criteria for applying those principles would be very difficult, if not impossible. Further, it was argued that the inclusion of a principle of prior consent in a legal regime governing direct broadcasting would render restrictions on program content unnecessary, particularly if prior consent were complemented by a principle providing for participation of the receiving state.[75] The related view was expressed that, if the conduct of direct broadcasting was to be governed by the key principle of international cooperation, the inclusion of limitations effectively dictating program content would be inappropriate.[76]

During the Legal Sub-Committee debates, the American position merged with the Swedish-Canadian positions despite the conflict between the two on the question of prior consent. They proposed a principle calling for cooperation between states with respect to programming, program content, production and exchange of programs.[77] The fourteenth session report also notes a position, like that advocated consistently throughout the debates by the Soviet delegation, which would require states to exclude, regardless of other agreements, programming material which: 1) is detrimental to the maintenance of international peace; 2) publicized war, militarism, nazism or racial hatred; 3) is aimed at interfering in the domestic affairs of other states; or 4) undermines local culture in any way.[78]

During the Working Group debates regarding program content, the question of the permissibility or commercial programming or advertising arose. One faction supported the view that to the extent direct broadcast advertising created a demand in the receiving state for a particular product or in any other way generated conditions unfavorable to local industry, such programming would be undesirable and should be permitted only when expressly permitted by the receiving state.[79] Other states argued that no distinction should be drawn between advertising or commercial programming and any other category of program content.[80] The same positions were taken in the Legal Sub-Committee, with the result that a third disputed paragraph relating to program content would permit commercial advertising only on the basis of prior agreements was incorporated in the session report.[81] During its 1976 session, the Legal Sub-Committee was unable to achieve progress on any aspect of the program content issue.[82]

10. Unlawful or Inadmissible Broadcasts

Closely related to the questions of prior consent and program content is a draft principle defining unlawful or inadmissible broadcasts. The first clause of the draft principle reported by the subcommittee is taken verbatim from Article VI of the draft principles presented to the fifth session of the Working Group by the Soviet delegation.[83] It provides that the international liability of states arises when either broadcasts are conducted without the express consent of the receiving state, or the broadcasts contain proscribed material, or when unintentional spillover is compounded by the broadcasting state's failure to enter into appropriate consultations with the receiving state.[84] The draft principle again drew from the Soviet proposals to the fifth Working Group when it authorized the receiving state to take any remedial measures recognized as legal under international law, without placing any priority upon negotiation, conciliation, arbitration or any of the other conflict resolution techniques preferred in the United Nations framework.[85] The states which opposed a direct broadcast regime based on program content limitations or prior consent, and consequently opposed outlawing any broadcast, rejected the draft principle in toto.

C. Prospects for Resolution of the Direct Broadcast Debates

When the direct broadcast debates began in 1963, they were not characterized by any special sense of urgency, since direct satellite broadcasting was neither technologically nor economically feasible in the foreseeable future. Since then the pressure to impose international controls to prevent potential abusive applications of the technology has increased sharply, primarily because of rapid, highly visible technological progress. NASA's experimental communication satellite programs, especially those using Application Technology Satellites (ATS) 1, 3, 5 and 6, and the operational successes of the Intelsat system have been particularly instrumental in overcoming technological barriers to direct broadcasting.[86] These experiments, combined with ambitious plans for more advanced experimentation, including the Indian-American SITE experiment and the Canadian-American CTS projects,[87] have motivated other countries to develop their own experimental or operational direct broadcast programs. At the Panel Meeting on Satellite Broadcast Systems for Education convened by CPUOS in Tokyo in April 1974, Japan announced that it would launch an experimental direct broadcast satellite in 1976,[88] and the Canadian and Brazilian delegations outlined plans to launch new domestic satellites to facilitate communications with their vast, remote hinterlands.[89] The French delegation offered free time on its Symphonie satellite to French-speaking African nations for educational programming,[90] and the European Space Research Organization announced plans to establish an operational regional broadcast system by 1980.[91] Indonesia and Iran announced long-range preparations for educational television broadcasting via satellite, and Malaysia discussed its program to install 5,500 television and radio receivers and 2,000 electric generators in rural locations in order to improve its national educational system.[92] Although the Malaysians plan to rely on terrestrial distribution, they could become users of the Japanese satellite if costs prove to be sufficiently low.

Although the technological developments justify some international institutional response, the magnitude of the response seems disproportionately large in comparison to the imminence of potentially abusive application. Examination of the United Nations debates in direct broadcasting indicate the presence of three factors which have disrupted the processes which normally operate to establish an equilibrium between the forces which motivate technological development and those which support the creation of a regulatory institution to control abuses of the evolving technology.

The first of these is the failure to gauge accurately the relationship between specific experimental developments and the final technical configuration of a direct broadcast system which could be used for the purposes cited by proponents of a restrictive international legal regime. For example, the report of the first Working Group concluded that satellite transmission of television signals direct to unaugmented home receivers was "not foreseen for the period 1970-1985," because present technology did not possess the means to transmit sufficiently powerful signals from satellites.[93] A number of governments erroneously interpreted this statement at future meetings of the Working Group to mean that telecasting directly to home installations would begin in 1985. Actually, the Working Group concluded that it would not be economically practical at any time before 1985, and perhaps not for some time after that.[94] National position papers submitted to later sessions of the Working Group based their analyses of the direct broadcast issues on the figures established during the first session. Not always accurate, the initial findings alarmed those nations concerned about propaganda and cultural imperialism, and may have added a note of urgency to their draft recommendations for the Working Group.

The second factor which has upset the normal equilibrium between technological and regulatory interests is the failure to assess realistically the limitations imposed on operational direct broadcasting by economic factors. In those more developed countries which have equipped themselves at great cost with an extensive terrestrial network for the distribution of television programming, transition to operational use of direct broadcast satellites would entail a radical realignment of the existing distribution patterns. In the United States, for example, transmission to home receivers would eliminate the need for local television stations, the common carrier land lines connecting the local stations with the central program production facilities of the major television network organizations and cable television companies. Understandably, therefore, special interest groups have opposed the use of direct satellite broadcasting for national programming. Until a reliable economic analysis balancing the cost of the necessary realignment against the benefits of a direct broadcast network has been made, countries already possessing extensive television distribution networks are not likely to make a rapid transition to direct broadcasting.

For those reasons, the newly evolved technology will probably be most beneficial to the less developed countries. Such states generally have television broadcast facilities which serve only a few major cities. The construction of a comprehensive national network using conventional ground facilities is often economically unfeasible due to the present cost of hardware. The broadcast satellite can dramatically reduce these costs, especially when serving a large geographic area, difficult terrain, or a widely dispersed population.[95] In addition, a direct broadcast television network could become operational in a fraction of the time needed to construct a terrestrial system based on cable and microwave. Both of these factors recommend direct broadcasting to such nations as Brazil, India and Indonesia, where topographical features prevent the construction of truly national television systems. Once operational, a direct broadcast system could contribute significantly to national development by facilitating national integration and improving the quality of the country's educational system.[96] In addition, users of direct broadcasting would probably reap other less direct benefits, including national economic development and access to foreign and international information resources.

Despite the relatively large range of advantages to be derived from direct broadcasting by those countries which do not yet have an extensive investment in terrestrial distribution systems, two main economic impediments still delay operational use by those countries. First, the cost of operating a direct broadcasting satellite system will still remain prohibitively expensive for individual less developed countries. At the United Nations Panel Meeting on Satellite Broadcasting Systems for Education, sponsored by CPUOS in Tokyo during February and March, 1974, the UNESCO representative presented an analysis of the financial requirements for satellite broadcasting, concluding that a viable system dedicated exclusively to educational television would require a population base of 100 million, assuming a gross national product of $200 per capita.[97] He further noted that other combinations of population and income could lead to viability, and that Iran, for example, could support a viable direct broadcast educational network with a population of thirty million, but a $1,000 per capita income.[98] By the same formula, if the annual per capita income were $100 -- the prevailing income level of many African and Asian nations -- it would take a population of 200 million to support the satellite system. In these cases, therefore, the introduction of satellite television will depend upon cooperative arrangements on a regional basis,[99] on the use of multipurpose satellites capable of telephone and data switching, as well as television broadcasting, and on international financial and technical assistance.

The second economic factor is the shortage and high cost of ground receivers. At present, few Third World states have an adequate number of receivers to make any form of television broadcasting useful. In Asia, for example, only Japan and Singapore have enough television sets per capita to meet the minimum standard established by UNESCO as necessary if television is to serve as a useful educational tool.[100] The shortage of standard receivers is compounded by the fact that, at the current state-of-the-art, standard ground receivers require extensive augmentation to pick up the relatively weak signals transmitted by the satellites now in orbit. Augmentation increases the price of both individual receivers and the entire receiver network.

The report of the first Working Group estimated the cost of modifications to standard television receivers necessary for use as community receivers at $150, while the cost for modification of home receivers was estimated at $40 - $270.[101] The high cost of the receivers places them beyond the reach of the vast majority of individuals in nearly every country.

Hence, in the absence of substantial governmental assistance, economic factors will prevent the establishment of a network of receivers which is both capable of receiving signals broadcast directly from outer space and large enough to justify the enormous investment needed to establish the space segment of a direct broadcast network. The necessity of governmental assistance in establishing the receiver network facilitates governmental control and hence provides added protection against potentially abusive application.

The third factor disturbing the balance between technological and regulatory pressures is the failure of direct broadcasting antagonists to understand the extent to which existing technical regulations perform the functions of the proposed international legal principles. The most important examples are the ITU regulations which restrict satellite telecasting to frequencies several times higher than those normally used by standard television receivers,[102] and those which require the broadcaster to use all means technically available to reduce as much as possible the signal radiation over the territory of other countries in the absence of an agreement to the contrary.[103] The first group of regulations increases the complexity and, therefore, the cost of the necessary receivers, thus reinforcing the economic factors limiting the application of direct broadcast technology. The second group is arguably identical in effect to the prior consent regime supported by advocates of a restrictive approach to the technology.

An international consensus on principles to govern direct broadcasting should strike an effective balance between the interests motivating technological progress and those advocating a restrictive regulatory response. At present an imbalance exists in favor of regulation, with the consequences, first, that the implementation of the technology is likely to be deterred, and second, that agreement in the international area is unlikely until an equilibrium is established. While policy considerations may dictate some regulation at this time, any regulatory scheme should reflect a realistic assessment of the impediments to technology applications already established by technical and economic factors and existing regulation. Although the delegates to the fifteenth session of the Legal Sub-Committee were unable to reach a consensus on the key issues of prior consent, program content and spillover, the foundation for compromise seems to be present, and an effective accommodation of the competing interests upon that foundation should bring to fruition attempts to establish preliminary international regulatory structures to direct the development of direct broadcast technology.

Negotiations in the Working Group and the Legal Sub-Committee have failed thus far to reach agreement on the key questions of prior consent, program content, spillover and equal access,[104] and the resolution of these points of conflict would make possible the establishment of a consensus on a full range of general principles to guide the development of direct broadcast technology. The evolution of national positions during the fifth session of the Working Group and the fourteenth and fifteenth meetings of the Legal Sub-Committee suggests that agreement will be reached in the next few years on a set of principles designed to protect the interests of those states concerned with direct broadcasting's potential for abuse without imposing undue restriction on, and consequently delaying, the development and operational implementation of the technology. The discussion below projects probable bases for compromise derived as a result of examination of the key points of conflict remaining after the May 1976 session of the Legal Sub-Committee.

1. *Limited Prior Consent*

The growing pressure for protection against real or imagined abuses of the technology suggests that the final declaration of principles probably will center around a provision which would permit direct broadcasting only when the receiving state has given its express consent. Nearly every proposal before the Working Group and the Legal Sub-Committee has recommended the establishment of a prior consent regime,[105] and the United States has been the only major dissenter.

Three main arguments have been raised against the adoption of a prior consent rule. First, prior consent is said to abrogate the principle of the free flow of information embodied in the Universal Declaration of Human Rights and other international instruments.[106] However, the principle, even if established as binding upon all nations, is not absolute. In the International Covenant on Civil and Political Rights, for example, Article 19(2) delineates the free flow principle. In the third paragraph of that article, however, certain restrictions are permitted, including those for the preservation of the rights and reputation of others, and the protection of the national security, the public order, and public health and morals. Also imposing limits on the free flow principle, Article 20 provides:

> 1. Any propaganda for war shall be prohibited by law.
>
> 2. Any advocacy of national, racial or religious hatred that constitutes incitement to discrimination, hostility or violence shall be prohibited by law.[107]

Thus, the argument that the principle of free flow of information would be improperly abrogated by a principle granting a receiving state a right of prior consent may exaggerate the scope and legal significance of the principle. A better approach would be to provide for a flexible balance with other principles.[108]

The second major argument against the prior consent principle is that any restrictive regulation is, for the near future at least, premature. The problems likely to arise with the use of direct satellite broadcasting cannot be effectively evaluated at this time, first, because the necessary technology is not yet adequately developed, and second, because no country has concrete plans to deploy an operational system capable of broadcasting directly to unaugmented receivers.[109] That argument could be allayed significantly by the decision to approve a declaration of principles rather than a binding treaty.

Another argument against prior consent is that although such a rule would dispel fears of intrusive transmissions, it could also frustrate the development of direct broadcasting technology.[110] Rejection of prior consent, however, seems equally likely to hinder rather than promote technological development.[111] The United States, for example, is interested primarily in broadcasting by commercial entities. If these entities intend to broadcast normal commercial programming based on advertising, most receiving states seem unlikely to take the steps necessary to make direct broadcasting commercially feasible, especially by encouraging production and installation of augmented receivers. If these elements are absent, direct broadcasting based on commercial programming would remain unprofitable for some time. If, on the other hand, broadcasters would provide only educational programming, direct broadcasting could become profitable, but only under contract with the receiving state. In that case, however, the receiving state would undoubtedly insist on some control with respect to frequencies used, broadcasting time, and at least to some extent, over the nature of the programming.

By accepting a prior consent rule, the United States could expect to derive important benefits, including the creation of an atmosphere conducive to early widespread implementation of operational direct broadcasting. The establishment of such a rule would facilitate bilateral and multilateral exchanges leading eventually to the creation of regional organizations for satellite broadcasting.[112] In addition, the United States could expect to gain support from those countries which traditionally support the free flow of information, but which have advocated a prior consent rule to prevent the imposition of one country's values on others through direct broadcasting.[113] Finally, rapid implementation would maximize the benefits the United States expects to derive from the export of direct broadcasting hardware and technical assistance.

The acceptability of a prior consent regime to proponents of the free flow principle is also dependent upon the content of other components of the legal regime. The Soviet Union, for example, has consistently tied its prior consent proposal to principles limiting program content.[114] The Swedish-Canadian proposals have omitted any mention of program content, preferring to leave any limitations to specific agreements between the broadcasting and receiving states [115] Since the negotiations necessary for a prior consent regime would probably give the receiving state some control over content, the Swedish-Canadian approach seems likely to prevail, because it gives adequate protection against offensive programming, while avoiding the difficult and excessively time-consuming process of negotiating a set of limits on program content which would be both effective and universally acceptable.

The Swedish-Canadian prior consent rule has, however, been criticized as giving inadequate protection to the free flow of information, because it fails to place adequate limits on the receiving state's right to deny its consent. As presently drafted, the joint proposal would apparently permit the receiving state to withhold its consent arbitrarily and without any obligation to consider the principle of free flow of information.[116] In addition, the Swedish-Canadian recommendations seem to permit the receiving state to withhold its consent on a program-by-program basis. Such an extensive right of review would permit prior restraint on free speech and would, by permitting official examination of each program, unnecessarily burden the flow of information across national borders.[117]

Two sets of limitations on a strict prior consent rule will probably result from the pressure to preserve an atmosphere conducive to technological progress. First, where the broadcast signal is not actually receivable in the receiving state with available equipment, consent is not likely to be required.[118] Second, the negative effects on the free flow of information of an unlimited consent requirement could be mitigated by tailoring the requirement closely to the optimum balance between the free flow of information and the purposes for conditioning the right to broadcast on the receiving state's consent. The 1972 UNESCO declaration on guiding principles for direct broadcasting distinguishes among four main categories of programming, and recommends basic principles for each type. Article V(1) declares that the main objective of direct broadcasting with respect to the free flow of information is "to ensure the widest possible dissemination among the peoples of the world, of news of all countries, developed and developing alike.[119] The second paragraph of Article V imposes no requirement on news broadcasts other than to make every effort to ensure factual accuracy and to identify the source of the news broadcast and, where appropriate, of particular news items.[120] In the case of direct broadcast news programming, the receiving state's right to consent will be limited to the right to demand assurances of the factual accuracy and identification of news sources.

Article VI of the UNESCO declaration establishes the right of the receiving state to determine the content of educational programming broadcast via satellite to its people and, in cases where such programming is produced in conjunction with other countries, to take part in the planning and production on an equal footing.[121] The receiving state's interest in preventing propagandistic or otherwise offensive programming is strongest with respect to educational programming. In that area, receiving states will probably secure a relatively unrestrained right to deny their consent.

The interest of the receiving state is somewhat weaker in the case of cultural programs, including artistic performances and sporting events. In such cases, the UNESCO declaration called for a balance between the enrichment of all cultures through cultural exchange, while respecting the values of each culture and the right of all peoples to preserve their cultures as part of the "common heritage of mankind."[122] Debates in the Legal Sub-Committee suggest the evolution of a consensus on a provision permitting the receiving state to deny its consent to cultural programming only where it can demonstrate that substantial harm to its own culture would result from transmission of the challenged program.[123]

The final programming category delineated by the UNESCO declaration related to commercial advertising. Implicitly recognizing the potentially disruptive influence of consumer-oriented advertising originating in more advanced societies, the UNESCO declaration called upon the broadcasting state to reach a specific agreement with the receiving state prior to the transmission of commercial advertising.[124] Since advertising is one of the programming areas most threatening to less developed states,[125] and since the free exchange of advertising is less essential to values underlying the free flow of information than other types of programming,[126] the establishment of a relatively unrestricted right of the receiving state to deny its consent appears probable. The inclusion of a principle giving the receiving state the right to deny its consent--subject to the conditions described above--to direct satellite broadcasts would provide an optimum balance between legitimate interests in both the free flow of information and national political and cultural integrity.

2. *Spillover*

Another criticism of the prior consent rule is that it would interfere with direct broadcasting by giving the right to deny consent not only to the intended receiving state, but also to any neighboring state inadvertently irradiated by the satellite.[127] Initially, spillover is not likely to be a major source of friction because the first direct broadcast systems will probably be national systems in large, underdeveloped countries, followed shortly by regional systems based on regional linguistic and cultural similarities.[128]

Once spillover becomes a source of conflict, however, the undesirable effects could be limited through the exercise of control by the government of the receiving state over community receivers. That solution, however, carries several undesirable consequences. First, the cost of avoiding the effects of spillover would be borne entirely by the receiving state.[129] The costs include not only the financial cost, but also the political costs of appearing to impose censorship for the benefit of the government. Second, government control of receivers would tend to subjugate freedom of information to direct and indirect assertions of national security interests.[130]

The Legal Sub-Committee is more likely to place the burden of reducing spillover on the broadcasting state, thereby providing some protection to the spillover states, while reducing the incentive for receiving states to exert international political pressure for broader restrictions. The growing consensus is based primarily on Article 7, §428A of the Radio Regulations adopted by the ITU at its 1971 convention. Paragraph 428A requires the broadcasting state to reduce spillover to the maximum extent practicable unless a prior agreement has been reached between the broadcasting state and the states receiving spillover.[131] Building on that foundation, the Swedish-Canadian proposal to the fourth and fifth sessions of the Working Group provided that the right of consent shall apply in those cases:

> (a) where coverage of the territory of a foreign State entails radiation of the satellite signal beyond the limits considered technically unavoidable under the Radio Regulations of the International Telecommunication Union or
>
> (b) where notwithstanding the technical unavoidability of spill-over to the territory of a foreign State, the satellite broadcast is aimed specifically at an audience in that State within the area of spill-over . . . .[132]

The Legal Sub-Committee could yield to pressure by the United States to extend the Swedish-Canadian proposal so that the limited prior consent rule as described above would apply in all cases <u>except</u> where:

1) the elimination of spillover is considered technically impossible under the present state of the art, as determined in accord with the ITU Radio Regulations;
2) the direct broadcast system is entirely domestic in character; or
3) the broadcast, although irradiating a part of the complaining state's territory, is not actually receivable using standard or easily augmented receivers readily available in the area irradiated.

A second paragraph would restore the right to deny consent where the spillover broadcast was aimed specifically at an audience within the receiving state. A third paragraph taken from the Soviet draft declaration submitted to the fifth session of the Working Group could be added to the spillover article to ensure that international cooperation and consultation will govern the relations between broadcasting and receiving states with regard to spillover:

> 1. If any State has reason to believe that activities connected with direct television broadcasting planned by that State will cause potentially harmful interference to other States or will lead to unintentional radiation of their territory, it shall hold appropriate consultations before undertaking such activities.
>
> 2. If a State has reason to believe that unintentional radiation of its territory will occur as a result of direct television broadcasts by another State, it may request that appropriate consultations be held. If, as a result of such unintentional radiation, foreign programmes can be received in the territory of a State by ordinary receivers or by receivers fitted with simple additional devices, the broadcasting State shall immediately enter into consultations with the former State on its request regarding the content of the programmes received.[133]

Participation or Equal Access

A further controversial issue is the question whether receiving states should participate in the use of direct broadcast systems. The 1972 UNESCO declaration of principles for direct broadcasting set forth the right of the receiving state to participate on an equal footing with any other state in the production of educational programming destined for the receiving state.[134] The Swedish-Canadian draft declaration submitted to the fifth session of the Working Group went further, giving the receiving state not only the right to deny its consent to satellite broadcasting, but also to participate in activities related to programming broadcast into its territory.[135] It has further been proposed that all states receiving broadcasts should have the right--in law and in fact--to have access to the system on an equal footing, including the rights of access to transmitters and to sufficient international assistance to enable those states to make meaningful use of the access rights.[136]

Both the UNESCO and Swedish-Canadian participation principles are intended to enhance the receiving state's ability to influence the programming broadcast to its citizens. In Article VI(2), the UNESCO version gives the receiving state the right to participate on an equal footing in the planning and production of programming, but only as an adjunct to the provision proclaiming the right of the receiving state to determine the content of educational programming.[137] By including its participation provision in the general prior consent paragraph, the Swedish-Canadian draft declaration extends the right to participate to encompass all types of programming and all stages of programming activities.[138] The inclusion of a right of participation for the purpose of ensuring the receiving state's power to affect the content of broadcasts beamed to it would alter the balance in favor of those interests demanding that the receiving states' cultural and political integrity be protected against the intrusion of unwanted foreign broadcasting over the interests in realizing the benefits of direct broadcasting through operational use. As a result, operational application would probably be delayed substantially.

A second rationale advanced for inclusion in the proposed declaration of a principle permitting the receiving state to participate in direct broadcasting over its territory is to give effect to the principle of free flow of information.[139] On numerous occasions, potential broadcasting states, particularly the United States, have based their arguments supporting an unrestrictive regulatory scheme for direct broadcasting at least partially on the contention that a restrictive regime would inhibit the free flow of information.[140]

Sound policy considerations support the integration of the free flow principle into the structure of legal principles to govern direct broadcasting. At present, the two most important requirements for effective development of satellite communication technology for operational use are, first, the uninhibited exchange and testing of information and ideas, and second, the assurance that the value of investments in development will not be nullified by the imposition of unnecessarily restrictive regulations upon innovative systems. A legal structure designed to promote rather than inhibit the free flow of information will encourage designers and planners to explore the potential uses and benefits of recent technical advances.

Viewed pragmatically, however, the principle of free flow of information is reduced to a fiction unless it is coupled with a second principle calling upon the international community to promote development of satellites and ground facilities in such a way as to facilitate access to transmitter and program production facilities by any state willing to contribute to development and operating costs. In the absence of an equal access clause, free flow of information would probably mean a unidirectional flow from the more developed countries to the less developed. The principle of free flow opposes not only unnecessary limitations on the influx of information from abroad, but also monopolization of a medium for ideological purposes.[141] That potential imbalance is the source of the fears of cultural and economic imperialism expressed by potential receiving states, with detrimental effects for both international cooperation and technology development. The inclusion of an equal access provision, however, would both allay those fears and set in motion a search for means to achieve the goal of equal access without sacrificing the interests of the broadcasting states.

Although an equal access principle is likely to be included in a declaration of principles, the lack of certainty regarding the circumstances under which operational direct broadcasting will be conducted makes necessary a particularly careful choice of language to avoid interference with the balance of interests established in the preceding discussions of the prior consent and spillover provisions. The form of the final participation provision probably will parallel the principle presented by the United States in its draft declaration submitted to the fifth session of the Working Group. This draft entitles every state to share in the benefits of direct broadcasting and provides further that such sharing "should increasingly include, as practical difficulties are overcome, opportunities for access to the use of [direct broadcasting] technology for the purpose of sending as well as receiving broadcasts."[142] As this right of access becomes available from a practical standpoint, allocation of transponder time should be made available on a non-discriminatory basis.

Presumably, a receiving state would exercise its right to obtain transponder time on a non-discriminatory basis at least initially for the purpose of transmitting its own programming to its own citizens. Self-sufficiency in that sense is desirable, and broadcasting states should be encouraged .rovide the technical assistance necessary to achieve that goal. To impose an obligation to provide such assistance is, 'owever, unnecessary since investment in technical assistance would provide a two-fold return. First, increased interest in direct broadcasting systems would accelerate demand for the exportation of the necessary technical equipment and software expertise from the broadcasting states.[143] Second, an increasing right of participation would create a greater community of interests between broadcasting and receiving states, with the result that the latter would promote rather than inhibit the operational application of direct broadcast technology.

II. IMPLICATIONS OF THE CPUOS DEBATES ON EARTH RESOURCES SATELLITES FOR SPACE INDUSTRIALIZATION

The second set of current activities which is likely to influence the future development of international space law centers around the CPUOS debates relating to international principles to govern the use of earth resources satellites. Consideration of the earth resources satellite issue began with the establishment of the Working Group on Remote Sensing of the Earth by Satellites.[1] The CPUOS Legal Sub-Committee devoted a small portion of its 1977 session to a preliminary review of relevant issues.[2] Since then satellite remote sensing has had significant attention in each subcommittee session.

A. Main positions

During the evolution of the satellite remote sensing debates, three major blocs have emerged. The main tenets of each position are represented in a series of three proposals for international guidelines for the use of earth resources satellite technology.

1. Argentina and Brazil: Treaty on Remote Sensing of Natural Resources by Means of Space Technology, Draft Basic Principles

At the 1974 session of the General Assembly, the delegations of Argentina and Brazil jointly submitted a draft treaty to govern satellite remote sensing.[3] The draft is now co-sponsored and strongly supported in all of its provisions by each of the other Latin American delegations represented on CPUOS: Mexico, Venezuela and Chile. Although a number of delegations privately express support for the Latin American submission, only the Latin American delegations have argued directly for adoption of the draft treaty.

The tone of the draft is established in its preamble, where it refers both to consequences of the implementation of remote sensing technology "which create legal problems that require an *immediate and equitable solution in the framework of a general treaty* . . ." and to the concept of permanent sovereignty over natural resources, which allegedly gives a state the sovereign right to control not only the natural resources located within its territory, but information regarding those resources as well. The need for a binding international legal framework is a recurrent theme in formal speeches and private conversations not only among the Latin American delegations, but among the Third World and Soviet bloc delegations as well.

The Latin American draft treaty proposes in Article V to implement the alleged rights of permanent sovereignty over natural resources by imposing a duty on any state engaged in earth resources satellite activities to refrain from gathering data from the territory of any state which had not consented. In addition, Article IX would prohibit any state obtaining information regarding the natural resources of another state through satellite remote sensing from conveying such information in any manner "to a third state, international organization *or private entity,* without the express consent of the [state] to which the natural resources belong . . ." If entered into force, these prohibitions would be strengthened by Article XIII which contains a provision similar to that in Article VI of the 1967 Outer Space Treaty[4] imposing on each state the responsibility to ensure the compliance of its nationals, including commercial entities, with established rules of international law. Article VI of the Latin American proposal would permit a party to the draft treaty to take all measures authorized by international law to protect its territory against any unauthorized surveillance. Both prohibitions could interfere with the provision of commercial earth resources services.

If one party to the proposed treaty authorized another to gather information regarding the former's natural resources, the draft treaty would provide the former with specified benefits. In exchange for its consent, Article VII would entitle the surveilled state to participate in the satellite remote sensing activities of the state granted consent on the basis of arrangements made during negotiation of consent, except that as a minimum such arrangements must include a guarantee that the sensing state will provide technical assistance to the consenting surveilled state. In addition, once the latter has given its consent, Article VIII of the draft would give it the right to full and unrestricted access to "all data obtained through those activities." That provision does not specify whether or not "all data" is limited to data related to the surveilled state's territory.

However, such an interpretation seems correct, in light of draft Article IX, which would prohibit the sensing state f·om distributing any earth resources data it had gathered relating to the territory of another state without the express consent of the surveilled state.

In summary, the Argentine-Brazilian Draft Treaty would:

1. impose legally binding obligations under international law;
2. subject satellite remote sensing activities to the prior consent of the sensed state;
3. subject data dissemination activities to the prior consent of the sensed state; and
4. require participation and broad-scale technical assistance as consideration for the consent of the sensed state.

2. France and the Soviet Union: Draft Principles Governing Activities of States in the Field of Remote Sensing of Earth Resources by Means of Space Technology

The second proposal currently before the Committee on the Peaceful Uses of Outer Space was presented jointly by the Soviet and French delegations in May 1974.[5] At present, the Soviet-French draft declaration enjoys monolithic support from the Eastern European members of the committee: Bulgaria, Czechoslovakia, the German Democratic Republic, Hungary, Poland, and Romania. In addition, the proposal shares with the Latin American draft treaty the support of a number of non-aligned and Third World countries including Egypt, Iran, Chad, Mongolia and Nigeria.

The theoretical underpinning of the Soviet-French draft resembles that of the Latin American approach, but differing interests have created some important divergences.

After restating the principles in Article I and III of the Outer Space Treaty relating to free use of outer space and compliance with international law and the United Nations Charter, the Soviet-French draft calls upon sensing states to respect in particular the principles of sovereignty, placing special emphasis on the right of a state to exercise permane·.. sovereignty over natural resources as a basic element of self- ·termin tion.[6] However, rather than applying strict prior consent provisions like that contained in the draft treaty to the gathering of earth resources data by satellite, the Soviet-French proposal would implement the concept of permanent sovereignty over natural resources primarily by granting the surveilled state the right to deny its consent to dissemination of information related to its resources to any private party, international organization, or other government, or using the data in any other manner detrimental to the interests of the surveilled state.[7] An exception would permit the sensing state to make public without the consent of the surveilled state information relating to natural disasters or phenomena detrimental to the general environment.[8]

In other respects, the draft declaration is similar to the Latin American proposal. Article 4 would require the sensing state to relay data regarding the territory of another state to the latter on mutually agreeable terms. In addition, the surveilled state would be granted the right to participate in the remote sensing activities of the sensing state on the basis of a consensus between the two states.[9] Finally, the Soviet-French proposal would permit any state to receive and process on the basis of equality and on mutually acceptable terms earth resources satellite information relating to territory outside the jurisdiction of any state.[10]

The primary reason for the Soviet Union's opposition to a prior consent regime with respect to data acquisition is that it intends to expand its activities in the field of remote sensing and does not wish to be limited by restrictive principles or treaty provisions. At the 1977 session of the CPUOS Scientific and Technical Sub-Committee, the Soviet delegation made numerous references to Soviet activities in the area of satellite remote sensing. The Soviet Union has attempted privately to persuade the United States to accept prior consent with regard to data dissemination in order to ensure ultimate adoption of an international regime which would not limit data acquisition activities.

The Soviet position on the question of commercial implementation of the technology should be carefully monitored, since the Soviets currently consider the sale of earth resources data and services to be inappropriate. Although it is possible that Soviet opposition is based solely on its argument that no legal basis currently exists for the sale of those items, a more credible explanation is ideological resistance to "capitalist enterprise." In the CPUOS debates on direct broadcast satellites, the Soviets have proposed that activities by non-governmental entities be prohibited.

If adopted, the Soviet-French draft declaration would:

1. not in itself impose legally binding obligations on members of the international community;

2. permit data acquisition via satellite in the absence of the prior consent of the sensed state;

3. subject data dissemination to the prior consent of the sensed state: and

4. place participation of the sensed state in the earth resources satellite program of the sensing state on a contractual basis between the two states.

3. United States: Remote Sensing of the Natural Environment of the Earth from Outer Space, Working Paper on the Development of Additional Guidelines

In the context of these drafts the United States issued a working paper based on the considerations that the optimum benefits from earth resources satellite technology will depend on international cooperation and the sharing and use of data on a regional and global basis.[11] The keystone of the working paper is the provision in Article I that remote sensing shall be conducted in

> accordance with the principles of the United Nations Charter, the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, and other generally accepted principles of international law relating to man's activities in outer space.

The reference to the 1967 Outer Space Treaty is particularly important in that respect, because it provides the legal foundation for the United States delegation's resistance to prior consent in any form. Article I(2) of the Outer Space Treaty provides:

> Outer space, including the moon and other celestial bodies, shall be free for exploration and use by all States without discrimination of any kind, on a basis of equality and in accordance with international law, and there shall be free access to all areas of celestial bodies.

The American delegation has argued repeatedly, first, that this "free use" principle authorizes all satellite remote sensing activities in the areas above the vertical limits of territorial sovereignty, subject only to the requirement that contemplated uses be peaceful in nature, and second, that a prior consent requirement would be in direct conflict with the "free use" principle.

Building on that foundation, Article IV calls upon states with satellite remote sensing programs to encourage the broadest feasible participation in appropriate phases of those programs. In addition, Article V would require states receiving earth resources data directly from satellites to make that data available "to interested states, international organizations, individuals, scientific communities and others on an equitable, timely and non-discriminatory basis." The same article encourages sensing states to facilitate sharing of earth resources data by publishing lists of publicly available data.

To dispel concerns about mineral or grain futures speculation based on early reception of data, Article VI would require a sensing state to distribute any data it acquires regarding the territory of another state to its government as soon as practicable, and at least as soon as to any state other than the sensing state. In addition, sensing states would be required under the American draft to facilitate direct reception of data from earth resources satellites by other interested states on equitable terms, if technically possible. Further, Article VIII calls upon sensing states "within their capabilities to endeavor to assist on an equitable basis" non-sensing states in understanding the techniques and benefits of satellite remote sensing. Articles IX and X encourage regional cooperation as well as assistance by internationa organizations for the purpose of facilitating operational applications of earth resources satellite technology.

The United States working paper differs in several significant respects from the two proposals described above. First, the Argentine-Brazilian submission is a draft treaty which, if entered into force would be legally binding upon the signatories. Although the Soviet-French proposal was presented in the form of a draft declaration, which would be non-binding if adopted, a large number of the delegations supporting that proposal have made reference both publicly and privately to the need for a binding international instrument, indicating reasonably strong support in that bloc for a treaty on remote sensing. In contrast, the United States working paper takes a much less concrete approach, at least from a legal perspective, offering instead "possible operative provisions." The starkness of the contrast is enhanced by the fact that the main issue of the debate over the form the final instrument should take is not whether it should be a treaty or a declaration of principles, but rather whether a declaration should precede the treaty or whether CPUOS should draft a treaty as the initial step. Most delegations are persuaded that the final instrument will be -- and ought to be -- a treaty. The only remaining question relates to the presence or absence of intermediate steps.

Second, the United States working paper rejects by omission the concept of permanent sovereignty, at least insofar as it is said to extend to the right to restrict access even to information regarding a state's natural resources. As a result, the working paper does not subject either acquisition or dissemination of earth resources data to the consent of the surveilled states. On the contrary, the American draft promotes a policy of open dissemination of data. That difference is important in light of the strength of the support for prior consent evidenced in speeches and private remarks by representatives of the members of the Committee on the Peaceful Uses of Outer Space.

Third, the working paper makes repeated reference to broad international participation in the remote sensing activities of space powers, technical assistance and regional cooperation. Although the other drafts make some reference to those principles, the American proposal takes a relatively strong position. The reasoning is that the defeat of an earth resources regime based on prior consent will only occur if the United States can demonstrate a strong likelihood that substantial benefits will inure to other countries if the American proposal is adopted.

Fourth, the proposal submitted by the United States would not, like the Latin American draft, impose international responsibility on each state for the activities of its nationals. The advantage of including such a provision in the instrument ultimately adopted is that it implicitly recognizes and authorizes non-governmental entities, especially corporations, to conduct operations in outer space. The potential disadvantage that the government would be responsible for enforcing international legal prohibitions against its own nationals is not a new disadvantage, since a similar clause appears in Article VI of the 1967 Outer Space Treaty. If such a provision were adopted by CPUOS in the context of earth resources technology, the private sector would be able to argue that an international consensus approving commercial satellite remote sensing activities has been established, and that domestic policy should be made consistent with that consensus.

In summary, the United States position is based on the following main principles:

1. no prior consent for either satellite data acquisition or data dissemination;
2. open dissemination of data to any customer;
3. dissemination to sensed state as soon as to any other government; and
4. broad technical assistance and international participation.

B. Current Status of the Earth Resources Satellite Debate

During its fifteenth session, CPUOS Legal Sub-Committee established a working group on the legal implications of remote sensing of the earth from outer space. On the basis of five "common elements" derived from the draft declaration submitted by the Argentine, Brazilian, Soviet, French, and American delegations, as well as from views expressed during the sub-committee's fourteenth session,[12] the working group formulated five draft principles applicable to satellite remote sensing during the 1976 session. In addition, the working group identified three new common elements.[13]

1. *Principle I*

As formulated by the Legal Sub-Committee, the first draft principle provides:

> Remote sensing of [the natural resources of the earth] [and its environment] from outer space and international co-operation in that field [shall] [should] be carried out for the benefit and in the interests of all countries [mankind], irrespective of their degree of economic or scientific development, and taking into consideration, in international co-operation; the particular needs of the developing countries.

Principle I is based on Article I(1) of the 1967 Outer Space Treaty which requires that the use of outer space be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development. The impact of the draft principle on operational implementation of remote sensing technology is dependent on the construction of the parallel language in Article I.[14] Some CPUOS delegations have argued that the treaty language entitles less developed countries to enjoy the benefits of earth resources satellite technology even though they are unable to conduct independent space programs. If that position became generally accepted, the range of institutional arrangements available to the United States for implementing a national earth resources satellite system on an operational basis would be limited. In particular, the option to provide earth resources information services on a commercial basis would be jeopardized. Because of the potentially adverse consequences for both national and international interests which could result from adoption of the restrictive interpretation of Article I of the Outer Space Treaty and Principle I of the draft declaration on satellite remote sensing, it appears that all states, including less developed countries, will benefit most from the combination of organizational and legal principles which promote initiation of earth resources information services on an operational basis as quickly as possible to the broadest range of potential users. If scope and quality of service provides the basis for international policy in this area, the restrictive approach would be dysfunctional. However, if national participation is considered by the international community to be more important than service characteristics, the interpretation of Principle I urged by the developing countries is likely to be adopted. The latter approach is.

however, not likely to be with the near-term interests of the entities which decide to invest in the industrialization of outer space.

The text of the draft principle contains three sets of bracketed words. The first pair was apparently inserted as a result of the suggestion by the United States delegation that the scope of the draft declaration be expanded from natural resources to include the entire natural environment.[15] In light of the possibility that the final declaration may be somewhat restrictive in character, an expansion of the scope of coverage has given rise to some concern in the private sector. The second pair of brackets resulted from disagreement among the CPUOS delegations regarding the strength of the declaration to be adopted. However, since the final product is likely to be a non-binding declaration of principles, the disagreement in this point is not considered significant.

The proposed use of the word "mankind" rather than the word "countries" in the third set of brackets may well result in increasing reference to the broader concept of the "common heritage of mankind." This broader concept has been embodied in General Assembly resolutions and negotiations relating to the law of the deep seabed,[16] as well as to the moon treaty presently under consideration by CPUOS,[17] and has been used by less developed countries to assure access on an equitable basis to the natural resources of both areas regardless of their ability to exploit them.[18] A parallel construction might enable a state to obtain satellite-acquired remote sensing information, regardless of its ability to pay for the information. Although mentioned here in the context of the remote sensing satellite debate, the notion that all states should have access to the products of space activities without consideration of financial ability to participate in these activities has potentially adverse implications for all facets of space industrialization. In particular, adoption of the "common heritage of mankind" approach could inhibit commercial participation in the development of outer space.

2. *Principle II*

The second draft principle formulated by the working group provides:

> Remote sensing of [the natural resources of the earth] [and its environment] from outer space [shall] [should] be conducted in accordance with international law, including the Charter of the United Nations and the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and other Celestial Bodies.

The language is consistent with and apparently based on the text of Article III of the Outer Space Treaty. In addition, the text is essentially identical to the text of the second common element formulated during the Legal Sub-Committee's fourteenth session.[19] The two sets of brackets were included as a result of the same general positions which necessitated inclusion of parallel bracketed terms in Principle I.

In its present form, Principle II would not have any adverse impact on optimum availability of benefits, unless either general international law or the terms of a remote sensing declaration were deemed to include such concepts as "prior consent," "the common heritage of mankind" and "permanent sovereignty over natural resources." To date the United States has been consistent in its opposition to adoption of prior consent principles with respect to both acquisition and dissemination of satellite-acquired data. The same approach should be taken with respect to the concept of "permanent sovereignty over natural resources," which has supplied one of the main policy foundations for prior consent arguments. As embodied in a series of General Assembly resolutions, the concept would give each state the right to control access not only to its natural resources but to information regarding those resources as well.[20] Although an examination of those texts demonstrates that the concept has not yet been extended that far, the extension would be accomplished by adopting a principle similar to that in a working paper submitted by Mongolia during the subcommittee's fifteenth session which provides.

> States participating in remote sensing should respect the principle of full and permanent sovereignty of all States and peoples over their wealth and natural resources as well as their inalienable right to dispose of their natural resources and of information concerning those resources.[21]

Because of the potential inhibiting effect it could exert on the establishment of an operational earth resources satellite system, the concept of permanent sovereignty should be limited to its current scope. Opposition to the Mongolian proposal is also considered important, because such opposition would undermine support for the extreme prior consent proposals. As a result, compromise would be facilitated in other areas.

3. *Principle III*

As drafted by the Working Group on Remote Sensing at the fifteenth session of the Legal Sub-Committee, Principle III provides:

> 1. States carrying out programmes for remote sensing of [the natural resources of the earth] [and its environment] from outer space [should] [shall] promote international co-operation in these programmes. To this end, sensing States [should] [shall] make available to other States opportunities for participation in these programmes. Such participation should be based in each case on equitable and mutually acceptable terms due regard being paid to elements . . .
>
> 2. In order to maximize the availability of benefits from such remote sensing data, States are encouraged to consider agreements for the establishment of shared regional facilities.[22]

Principle III is based on two common elements identified by the Working Group on Remote Sensing during the fourteenth session of the Legal Sub-Committee.[23] According to the session report, the delegations agreed:

> 1. that the maximum benefits to all countries could be obtained by international co-operation at all levels, particularly on a regional basis; and
>
> 2. that States undertaking programmes for remote sensing activities by means of space technology should encourage international participation.[24]

The texts of the draft principle and the underlying common elements raise the question of the meaning of the terms "cooperation" and "participation" and the relationship between the two. Article I(3) of the Outer Space Treaty requires states to "facilitate and encourage international co-operation in (scientific) investigations." Since the term "co-operation" is not used again in any operative provision which relates to activities in outer space,[25] it may be construed in the limited context of Article I(3) relating to scientific investigation. Thus, "co-operation" is not necessarily mandated, except for experimental activities. The Outer Space Treaty does not give any significant clue to the meaning of "co-operation." The fact that Paragraph 1 of Principle III refers to the promotions of "international co-operation <u>in</u> (the) programmes" of sensing states suggests that the working group equated "co-operation" with "participation." That inference is supported by the second sentence of Paragraph I which establishes "participation" as the most important element, if not the only element, of "co-operation."

Actual foreign participation in programs conducted by the United States or its nationals would jeopardize corporate interests. First, to the extent that the federal government permits foreign participation, the alternatives for interface between the public and private sectors are limited. If, for example, the federal government cooperates in the construction of an extensive network of readout stations for distribution of raw data, it cannot logically support commercial implementation. Second, foreign participation in profit-oriented operations would both undermine the commercial basis and jeopardize United States technological leadership. Similarly, significant participation in United States programs is likely to result in international pressure to limit providers of data and services to activities in their own regions, thus reducing both competition and the quality and scope of services available to users.

The United States delegation is not likely to support deletion of the references to participation, because it has supported strong cooperation and participation as a means of avoiding imposition of prior consent principles. In fact, the draft declaration submitted by the United States delegation during the thirteenth session of the Legal Sub-Committee contains the provision that:

> States undertaking programmes designed for remote sensing of the natural environment from satellites shall encourage the broadest feasible international participation in appropriate phases of these programmes.[26]

Three alternatives for minimizing these difficulties could be considered. First, Paragraph 1 of the third principle could be amended to limit its scope to experimental activities. Second, the language relating to participation could be made discretionary rather than mandatory, and could be limited as provided in Article 4 of the working paper submitted by the United States delegation during the thirteenth session of the

Legal Sub-Committee to "feasible participation" in "appropriate phases" of United States programs. Third, the paragraph could be amended to limit the participation foreseen therein to governmental, as distinguished from commercial, programs.

The language in the final sentence of Paragraph 1 relating to the terms of participation raises another problem of construction. That sentence, which places participation on the basis of "equitable and mutually acceptable terms," appears to be a broadened version of Article 5(a) of the draft declaration submitted jointly by the Soviet and French delegations which would have entitled any state whose territory is affected by the remote sensing activities of a second state to participate in the latter's program on "equal and mutually acceptable terms." Although the phrase "mutually acceptable terms" appears to be a broadened version of Article 5(a) of the draft declaration submitted jointly by the Soviet and French delegations which would have entitled any state whose territory is affected by the remote sensing activities of a second state to participate in the latter's program on "equal and mutually acceptable terms." Although the phrase "mutually acceptable terms" appears to provide a basis for commercial implementation, questions of interpretation could arise, since the source of the provision suggests an intention to place implementation on a non-commercial basis. Further, the omission from the draft principle of the language in the Soviet-French draft which implicitly limits participation to those states affected by the remote sensing program in question would expand the scope of foreign participation and hence exacerbate the adverse consequences of such participation. The most desirable solution to the problem appears to be to ensure that any participation provision is discretionary in nature and limited to those states which are significantly affected by the program in which the sensed state wishes to participate.

The impact of the second paragraph of Principle III on operational implementation depends on the organizational or institutional configurations selected for routine operations. If, as suggested by CPUOS, complete reception and data management facilities are to be established in each region, the international market for private sector services could be significantly diminished. Consequently, the regional facilities recommended in Paragraph 2 of Principle III should be limited to facilities for specialized processing of preprocessed data and distribution of information products.

4. *Principle IV*

The fourth draft principle formulated by the Working Group on Remote Sensing provides:

> Remote sensing [of the natural resources of the earth] [and its environment] from outer space [should] [shall] promote the protection of the natural environment of the earth. To this end States participating in remote sensing [should] [shall] identify and make available information useful for the prevention of phenomena detrimental to the natural environment of the earth.[27]

In its present form, the language of the fourth principle would not adversely affect implementation of the technology, even if made mandatory. The use of information products as implied in the second sentence for the prevention of phenomena detrimental to the environment could expand the market for earth resources information products. However, to ensure implementation of this principle in a manner consistent with practical operational considerations, recipients of the information should be identified as international organizations responsible for environmental management and to governments of states likely to be affected adversely by phenomena detrimental to the environment. That limitation could be incorporated through the addition of language at the end of the text which would make available to all states likely to be affected and to concerned international organizations. In addition, the information should be made available on "mutually agreeable" terms.

5. *Principle V*

The fifth draft principle provides:

> States participating in remote sensing of [the natural resources of the earth] [and its environment] from outer space [should] [shall] make available technical assistance to other interested States on mutually agreed terms.[28]

If implemented in its present form, Principle V would create pressure to export every facet of earth resources satellite technology and related ground technologies. That pressure could undermine both United States technological leadership and the basis for the provision of commercial earth resource information services not to mention possible national security concerns. However, if the provision were limited to technical assistance relating to specialized processing of data products and to the creation of infrastructures in less developed countries capable of applying information products effectively, it would be more likely to result in rapid national and regional development than would concentration of efforts on the sale of expertise, reception and preprocessing equipment. Since that approach would expand rather than contract the international market for the services not only for providers of satellite data services but for American exporters generally, the focus on infrastructure development appears desirable. Similarly, since "information" rather than "data," as those terms are defined by the Working Group on Remote Sensing[29] is the source of the benefits to be derived from satellite remote sensing, the emphasis of international cooperation and technical assistance programs should be placed on the acquisition and application of "information."

6. *Principle VI*

During its 1977 session, the Legal Sub-Committee formulated a series of new draft principles, based either on previously identified common elements or on a consensus established during the 1977 session.[30] The first of these is Principle VI which provides:

1. The United Nations and its relevant specialized agencies [and the International Atomic Energy Agency] [should] [shall] promote international cooperation, including technical assistance, and play a role of coordination in the area of remote sensing of [the natural resources of the earth] [and its environment].

2. States conducting activities in the field of remote sensing of [the natural resources of the earth] [and its environment] [shall] [should] notify the Secretary-General thereof, in compliance with article XI of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies.

This principle was based on the first of the common elements identified during the 1976 session.[31] In its present form, Principle VI makes a general statement regarding a possible coordinating role for the United Nations which would be desirable from the perspective of the United States if implemented within the limits described in the discussion of Principle V. The second paragraph merely applies Article XI of the Outer Space Treaty to satellite remote sensing and is considered inoffensive, provided the level of information required does not exceed the nature and scope of information currently supplied regarding satellite launches.

7. *Principle VII*

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Principle VII, which provides:

Information obtained by remote sensing [of the natural resources of the earth] [and its environment] indicating an impending natural disaster shall be disseminated as promptly as possible to those States likely to be affected.

was based on the second common principle identified during the 1976 session of the Legal Sub-Committee.[32] Adoption of this element in its present form also appears desirable. If included in a package of general services, the disaster warning

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service could be used to demonstrate to other delegations that the value of potential benefits significantly exceeds the cost of potential abuses of earth resources satellite technology.

8. Principle VIII

Principle VIII provides:

> Taking into account the principles I and II above, remote sensing data or information derived therefrom [shall] [should] [not] be used by States [to the detriment of] [in a manner compatible with] the legitimate rights and interests of other States.

Based on the third common element,[33] that language is closely related not only to the concept embodied in Article IX of the Outer Space Treaty that states should conduct their space activities with due regard to the corresponding interests of other states,[34] but to the interpretation of Article I(1) urged by developing states which would prohibit activities in outer space, unless they are conducted "in the interests and for the benefit of all states."[35] Because of those similarities, Principle VIII is likely to generate similar controversies, particularly regarding the construction of the term "international detriment."

The bracketed phrases permit both a negative and a positive interpretation. However, from the perspective of potential private sector interests, both approaches could be considered detrimental, when read in the context of Article VI of the Outer Space Treaty which imposes international responsibility on states parties to the treaty for the space activities of their respective nationals, whether governmental or non-governmental entities.[36] Broad or uncertain construction of the terms of Principle VIII could lead to restriction of legitimate, desirable activities, particularly based on commercial initiatives. Although private sector operations may be possible within the framework of such a principle, adverse political repercussions resulting from disputed constructions of the common element are considered both probable and detrimental to United States interests. Consequently, in its present form, the eighth draft principle is considered undesirable.

9. *Principle IX*

The ninth principle incorporated in the new draft was agreed upon during the 1977 Legal Sub-Committee without prior consideration during the 1976 session. Principle IX provides:

> States participating in remote sensing [of the natural resources of the earth] [and its environment], either directly or through relevant international organization [shall] [should] be prepared to make available to the United Nations and other interested States, particularly the developing countries, upon their request, any relevant technical information involving possible operational systems which they are free to disclose.

The apparent rationale for inclusion of this provision is to promote exchange of information regarding the characteristics of operational systems as a means of enabling developing countries to keep pace with technical and institutional developments. Since the availability of this type of information is likely to alloy some of the concerns of less developing countries concerning potential abuses of the technology, this level of information exchange is considered desirable.

10. Principle X

The second new principle formulated during the 1977 session provides:

> States [shall] [should] bear international responsibility for [national] activities of remote sensing [of the natural resources of the earth] [and its environment] [irrespective of whether] [where] such activities are carried out by governmental [or non-governmental] entities, and [shall] [should] [guarantee that such activities will] comply with the provisions of these Principles.

In essence, Principle X restates the provisions of Article VI of the Outer Space Treaty, and hence, does not necessarily increase the potential burdens imposed by the supervision requirement of that article. However, the fact of the restatement combined with the potential for more direct language indicates the existence of a trend toward full-scale national governmental supervision of all space activities. Consequently, Principle X has given rise to some concern in the private sector regarding the possible limitations on non-governmental space activities.

11. Principle XI

The final draft principle formulated this year by the Legal Sub-Committee provides:

> A sensed State [shall] [should] have timely and non-discriminatory access to data obtained by remote sensing [of the natural resources of the earth] [and its environment] from outer space, pertaining to its territory on reasonable terms [to be mutually agreed upon with the sensing State] and to the extent feasible and practicable, [shall] [should] be provided with such data on such terms [on a continuous and priority basis] [and in any case no later than any third state].

In some respects, this draft principle appears to correspond to certain of the positions taken by the United States in an attempt to avoid adoption of a prior consent regime. Particularly important are the classes relating to "timely and non-discriminatory access" and access "in any case no later than any third state." If ultimately adopted, the language of Principle XI could serve to limit the flexibility of operations available to the entity managing the system. In its present form, Principle XI could interfere with traditional private sector management and marketing procedures and should therefore be carefully examined prior to final adoption.

C. Prospects for Resolution of the Earth Resources Satellite Debate

The main tenet of the present United States policy is strict opposition to the adoption of an international regime based on prior consent. This approach is essentially consistent with the interests of the public and private sector. If data acquisition were subject to the consent of the surveilled state, as proposed in the Latin American draft treaty, acquisition procedures would be disrupted, causing increased costs while decreasing the value of the data. Strict adherence to the prior consent rule on data collection would require the capability either to turn off the satellite sensors, or to separate out and dispose of information pertaining to the territory of a state which had not given its consent. The first approach would increase the cost of satellite construction and operation, and the second would increase processing time and costs. Both approaches would be complicated by fluctuating geographic patterns of consent, especially in politically unstable regions. These consequences would affect the viability of both international and domestic earth resources services, regardless of the institutional configurations employed. In particular, with respect to operation of the space segment, the principle of prior consent would force operational entities to negotiate directly with foreign governments, which would in turn give rise to all of the problems which characterize relations between a sovereign and non-sovereign entity.

Related complications would arise if data dissemination were subject to prior consent. Both the Soviet-French and Latin American drafts would prevent transfer of satellite-acquired earth resources data from the government operating the satellite to any third party, public or private, without the express authorization of the surveilled state. If strictly construed, those provisions could prevent the United States government from distributing data to its own nationals, unless permitted by the foreign government in question. Strict construction seems warranted, since the provision would be meaningless if the United States government were free to disseminate all of the earth resources information in its possession to its nationals, who would in turn be free to convey the same information to any other entity, public or private.

In the absence of foreign governmental consent, American public and private entities could be inhibited from providing effective services in border areas, both because of the problems of spillover and because of the inability to provide services regarding phenomena affected by stimuli which originate or operate exclusively in foreign territories. Although the domestic market would enjoy the advantages of the relatively cordial relations between the United States and the adjacent countries, the delays and potential instability associated with consent relationships would make the situation undesirable.

The same problems would be exacerbated in the international market. In most regions the relatively small areas controlled by each government would increase the problems arising from the need to incorporate information from the territories of another state into an effective analysis of conditions in the consenting state. In the same regions border tensions and other forms of competition between neighboring states will interfere with the process of securing the necessary authorizations. Even where consent is initially obtained, continuation is dependent on political factors.

As noted above, one of the main policy foundations for the prior consent proposals has been the argument that the concept of "permanent sovereignty over natural resources" embodied in a series of General Assembly resolutions gives a state the right to control access not only to its natural resources but to information regarding these resources as well. An examination of those texts demonstrates that the concept has not yet been extended that far. To date, the United States delegation has not demonstrated particularly strong opposition, probably because of the political dynamics within the Outer Space

Committee. Limitation of the concept of permanent sovereignty to its current scope could weaken support for the extreme prior consent proposals and make possible compromise on some basis which permits relatively free access to data.

As an alternative to the prior consent proposals, the United States delegation has offered a strong policy of open dissemination of data. One of the main arguments against prior consent is that a prior consent regime would either defeat implementation of the technology altogether or give a monopoly on remote sensing data to those highly industrialized states capable of operating their own satellites. Under the open dissemination policy sensing states would make data "available to interested States, international organizations, individuals, scientific communities and others on an equitable, timely and non-discriminatory basis." Although the current United States policy could exclude the sensing state from the non-discrimination requirement and could in theory permit earlier access to its nationals, the non-discrimination aspect suggests that the State Department may be tending away from policy choices--and hence institutional configurations--which would permit access to earth resources satellite data prior to complete circulation through the federal Landsat processing network.

Another potential disadvantage could arise from the fact that the United States usually bases its argument in favor of open dissemination on the fact that the Landsat program has made a vast amount of information available to states which otherwise would have had no opportunity to secure it. The response has been, first, that NASA's current dissemination policy is entirely unilateral in nature and is therefore subject to unilateral alteration, and second, that the United States has not provided any assurance that the Landsat program will be continued on medium-term -- much less, a long-term -- basis. In its effort to secure a consensus on its open dissemination policy, the United States may feel compelled to commit itself to continuation of federally supported earth resources programs for the foreseeable future. The legislation introduced by Senator Ford to establish an operational earth resources satellite system under the control of NASA and the Department of the Interior would be consistent with that approach.[37] Because of reliance interests developed by other governments, a decision to utilize an organizational structure or selection of a means of distribution substantially different than the present method of selling partially refined data at the cost of reproduction is likely to subject the State Department to serious foreign pressure.

The third major element of current United States policy is the encouragement by sensing states of the broadest feasible international participation in appropriate phases of their respective programs. To facilitate that goal, the United States has proposed that sensing states should provide, within the limits of their capabilities, assistance to other interested states regarding the acquisition, interpretation and application of satellite-gathered earth resources data. The implication is that the United States government will continue encouraging other governments to participate in its Landsat program by establishing national or regional ground stations and data interpretation facilities. Participation and technical assistance are likely to generate a dependence among other countries upon U.S. government programs, thus increasing the international pressure to continue or even expand the current programs. The scope of the assistance actually provided will determine the extent to which the combination of readily available data and essentially gratuitous transfer of applications expertise will jeopardize the viability of the international marketing activities. However, in light of United States foreign policy interests, the level of assistance is likely to become substantial.

Although the differences between the interests of the Carter Administration and those of previous administrations may cause some changes in present United States policy, a number of considerations are likely to diminish the magnitude of any policy shifts. First, the federal government has a number of interests which would be advanced by an open data dissemination policy enhanced by technical assistance efforts. The federal government is primarily interested in procuring the benefits of satellite remote sensing technology for its citizens. Among these benefits are increased supply of raw materials, increased information for managing the national economy and enhanced ability to monitor the national environment for purposes of preventing or reversing environmental degradation. Consequently, the government is concerned that the policies it advocates will facilitate: a) effective, accurate service; b) on a real-time basis; c) at a reasonable cost.

A second primary interest is the selection of a combination of national and international policies which will develop the technology to operational status as soon as possible consistent with the realization of other goals. Third, the federal government is concerned that it reduce its expenditures as far as possible consistent with the achievement of other goals. The implications of this consideration are complicated by the fact that the government has a potential dual role as both provider and consumer of earth resources data services.

Fourth, federal policymakers are interested in expanding exports through satellite remote sensing in two ways. First, by promoting the international role of earth resources data and receiving and data processing equipment, the United States would improve its balance of payments and generate the foreign policy benefits discussed below. The federal government probably also intends to use earth resources satellite data at a second level as a tool, first, to develop previously underdeveloped food and mineral resources in order to increase supply and decrease world raw materials prices, and second, to encourage other states, especially the developing states, to use revenues from their increased volume of raw material exports to increase their imports, particularly from the United States. This broader approach seems to promise greater benefits for the

United States economy as a whole. That promise is increased by the apparent tendency of the American economy, *vis-à-vis* the economies of other countries, to specialize in the provision of information services. To maximize the benefits of the broader approach, access to earth resources data must be extended as far as possible.

Fifth, federal policy has traditionally enabled American private enterprise to exploit technology for commercial purposes, but the tendency has been limited by the extent to which other governmental interests have outweighed the interest in promoting commercial involvement.

In addition to those domestic policy factors, the United States has a wide range of foreign policy interests which could be affected by its choice of an international remote sensing policy. The first of those interests is the desire to continue reaping the benefits of other nations' recognition for United States technological leadership. To accomplish that goal, continued research and development is essential, indicating the need for continuing federal involvement in the earth resources field. Further, the United States must be able to demonstrate highly visible technical progress. On a more subtle level, these prestige benefits are also contingent on showing that the benefits of technological progress extend beyond the borders of the United States to less advanced countries.

The second set of foreign policy interests centers around the use of satellite remote sensing as a foreign policy tool.

If the U.S. government retains some measure of control over the allocation of earth resources data and services, it will be able to use the technology as a reward-or-punishment tool to advance its other foreign policy interests. Transfer of control to the private sector, however, would limit the flexibility of the tool.

The avoidance of foreign policy disadvantages could also militate against selection of a policy conducive to transfer to private enterprise. A profit-oriented organization is not likely to be especially concerned about the international political ramifications of the uses made of its work products by customers of refined earth resources data. Consequently, aggravation of international disputes could result particularly with regard to boundary placement in regions where satellite imagery indicates the existence of valuable natural resources. Blame would fall on the United States, even if its system were not operated by the government. Government control could limit the adverse consequences.

Similarly, government control could limit the negative response sometimes generated by an aggressive profit-oriented applications program. Direct profits for the earth resources industry might be reduced, but the benefits to the whole economy might, as noted above, be greater over time. Concerns expressed in the United Nations regarding the potential for economic imperialism if earth resources satellites were operated by a single government or private entity may lead the State Department to favor some inter-governmental arrangement designed to give at least the appearance of international control.

The third disadvantage to be avoided by non-private control of earth resources activities is the problem of international backlash which could result from transfer to the private sector. NASA has entered into a number of bilateral agreements with other governments for cooperation on earth resources satellite experiments. Each of those agreements calls for NASA to permit access to its Landsat system, and the other party agrees to construct an earth station and pay its own costs of participation. In addition, NASA has made attractive proposals which would encourage other states to invest in earth resources technology. In 1970, NASA proposed that the United States government adopt a program under which launching states would make data available to interested states at the cost of duplication, while a special United Nations facility would be established initially to service such United Nations agencies as the Food and Agriculture Organization (FAO) and the Economic and Social Council (ECOSOC), and later to assume such other responsibilities as were assigned to it by the world community.[38] Four years later, at the third session of the CPUOS Working Group on Remote Sensing, the United States offered to provide any international earth resources center with a master copy of the data collected during NASA's experimental ERTS program.[39] The agreements and offers by the United States combined with reliance by other states created international pressure on the federal government to continue providing some level of Landsat services. Transfer of its responsibility to a private entity would eliminate such unprofitable services, probably causing a backlash among other states.

Achievement of all of the foreign policy goals and most of the other goals described above is dependent at least in part upon extensive international participation. Consequently, the combination of national and international policy choices by the United States are likely to be designed in such a way as to make it clear to foreign governments that participation in the proposed international system would substantially advance their respective national interests. A policy essentially transferring responsibility for earth resources satellite technology to the private sector would complicate the prospects for international participation.

In addition to its own interests, the State Department is likely to consider the interests of other federal agencies, most significantly NASA and the Department of Interior. In furtherance of NASA's statutory mandate to promote the widest feasible application of space technology on both the national and international levels, NASA and its Office of International Affairs are actively supporting continuation and expansion of the network of memoranda of understanding between NASA and foreign governments. Expansion of the network could generate increased international opposition to discontinuation of the international aspects of the Landsat programs. Further, proliferation of ground stations could overcome some of the impediments to the establishment of an inter-governmental consortium, which could seriously limit the international market for commercial earth resources services. A policy of intergovernmental implementation on the international level would also strengthen the arguments for provision of earth resources services by a federal agency or federally chartered entity.

The Department of Interior and the U.S. Geological Survey are promoting a policy consistent with their proposals to improve and expand the Sioux Falls installation to facilitate transfer of data to both domestic and international customers. Increased federal involvement at that point in the Landsat system is likely to diminish the probability that private entities will be permitted access at an earlier point in the system.

Other elements, particularly from the academic community, are pressing for a U.S. policy in the United Nations which would make available throughout the world both earth resources data and the knowledge and hardware needed to apply the data. Those initiatives generally evidence a distrust of the commercial approach, particularly with respect to socially useful, but generally unprofitable applications.

The foregoing analysis of current trends in the CPUOS debates relating to principles to govern the use of earth resources satellites is relevant to general considerations in two main ways. First, under the definition of space industrialization set forth in Part I above, satellite remote sensing constitutes one of the four main categories. Second, a comparison of trends in the direct broadcast and earth resources satellite debates indicates that common trends can be identified. Consequently, those trends and the underlying complex of national interests provides the basis for projection of related trends applicable to other types of space industrial activities. As described more fully in Part V below, tendencies apparent from the debate surrounding the draft principles discussed in Subsection B above, suggest that the majority of CPUOS delegations favors a relatively restrictive approach to the development of outer space. This trend, combined with parallel responses in the domestic policy making process, could lead to establishment of international principles which limit the range of available institutional options and hence the character of potential participants in space industrialization.

III. IMPLICATIONS FOR SPACE INDUSTRIALIZATION OF THE CPUOS DEBATES ON THE DRAFT MOON TREATY

The first initiative to establish international principles to govern the use and exploration of the moon occurred in 1970 when Argentina submitted a proposal to the United Nations calling for promulgation of appropriate rules.[1] However, significant activity in the United Nations in that area did not occur until the Soviet Union introduced a draft moon treaty in June 1971.[2] In response, the General Assembly directed the Committee on the Peaceful Uses of Outer Space (CPUOS) to consider and elaborate upon the Soviet draft treaty at its fourteenth session, held in New York in September 1971.[3] The Outer Space Committee referred the draft treaty to its Legal Sub-Committee for detailed consideration at its eleventh session in April and May 1972. Despite significant differences of opinion among the delegations, the subcommittee was able to formulate a unified negotiating text consisting of a preamble and twenty-one draft articles. However, certain provisions were stated in alternative forms, indicating disagreement among the delegations as to those provisions. As a result, consideration of the treaty was continued the following year.[4]

The Legal Sub-Committee again examined the draft moon treaty at its twelfth session in March and April 1973, and several working papers were submitted by various delegations. Six provisions were adopted by the Legal Sub-committee which modified the 1972 draft somewhat and focused the remaining disagreements around three main issues:

1. scope of the treaty;
2. disposition of lunar resources; and
3. character and scope of information about the objectives of lunar missions to be made public prior to their commencement.

Since 1973 the same issues have remained unresolved and have prevented final approval of a moon treaty.

A. Current Status of the Moon Treaty Debate

Since 1973 three main issues have remained unresolved and prevented establishment of a final consensus on a draft moon treaty to be submitted to the General Assembly. The questions relating to the disposition of lunar resources are considered the most difficult, and its solution is expected to permit resolution of the remaining issues.[5]

1. *Natural Resources*

The main positions among CPUOS delegations on issues relating to the exploration and use of the moon are most clearly crystallized on the question of the disposition of lunar resources and its four major subissues:

1. the impact of Article II of the Outer Space Treaty;
2. the impact of the evolving concept of the common heritage of mankind;
3. the desirability of deferring regulation of lunar exploration and use until those activities have become imminent;

4. the desirability of declaring a moratorium on the exploitation of lunar resources pending establishment of an international consensus on the disposition of lunar resources.

For purposes of clarity, this discussion will consider the question of lunar resources from the perspective of these subissues.

a. Article II and National Appropriation of Lunar Resources

Since 1973 two main positions on the question of national appropriation of lunar resources have emerged. The United States takes the position that the Article II prohibition against appropriation of the moon and other celestial bodies does not prohibit acquisition of propriety rights in the natural resources of the moon.[6] They interpret Article II as prohibiting a state from exercising sovereignty over parts of the moon, but not prohibiting a state from gaining proprietorship over goods, including natural resources, which they take or "capture" from the moon.[7] This conceptual distinction between prohibited sovereignty and permitted proprietorship of natural resources is based on the provisions in Articles I and III of the Outer Space Treaty, which expressly permit states to "use" the moon.[8] As a result, those delegations argue that prohibition of ownership of the natural resources of the moon would require alteration of existing law as embodied in the Outer Space Treaty.

The Soviet position reaches the same conclusion by somewhat different reasoning. The Soviets advocate strengthening the Article II prohibition. In particular, they argue that the right of states to explore and use the moon, and the practical establishment of moon stations, does not create an ownership right to the surface or subsurface.[9] However, as made clear in the Soviet Draft Moon Treaty, the Soviets would expand and clarify Article II by expressly enumerating the entities to whom this prohibition allegedly applies. Under the Soviet approach, the prohibition would cover international organizations, private organizations, and individuals, as well as states.[10] However, the Soviet delegation argues that the Article II prohibition does not apply to natural resources, and that the rights to these resources for exploitation for either local moon requirements or for transportation to Earth are not defined in the Outer Space Treaty.[11] Both delegations agree that the status of the moon's natural resources should be determined in the moon treaty without any restrictions due to the ban on national appropriation in Article II of the 1967 Outer Space Treaty; instead, beneficial ownership of such resources would be given to those states that are actually making use of them.

The point of view espoused by the United States, the Soviet Union and other potential space powers is opposed by a bloc of developing countries, led by the delegation of Argentina. The Argentine position recognizes two classes of ownership.

The first, direct or eminent domain, is considered prohibited by Article II. The second, beneficial ownership (domain útil) is the enjoyment, receipt of the fruits and profit derived from property which is either unowned or commonly owned.[12] Because of their support of the principle of the common heritage of mankind, the developing countries maintain that lunar resources are owned in common by all members of the international community and is protected against national appropriation by the provisions of Article II.[13]

b. The Impact of the Concept of the "Common Heritage of Mankind"

Closely related to the issues surrounding application of Article II to lunar resources is the question of the applicability of the evolving concept of the "common heritage of mankind." Professor Aldo Armando Cocca, who heads the Argentine delegation, is the concept's leading advocate. In essence, the common heritage principle would secure beneficial ownership (domain útil) of lunar resources for all members of the international community. Consequently, if adopted, that concept would prevent individual states from appropriating lunar resources for individual use; instead, some form of sharing arrangement would be mandated. Such arrangements could require equitable allocation either of the resources extracted from the moon or of profits derived from the sale of these resources.

Professor Cocca admits that both negative and positive consequences are to be anticipated from granting beneficial ownership of the moon to all of the states. The projected negative aspects -- including inhibition of commercial initiatives -- would affect only those countries which now have the capacity to reach outer space. However, Professor Cocca maintains that all states, including the space powers, will benefit from lunar development on that basis. In particular, Professor Cocca has identified the following specific benefits:

-- a realization on the part of all States and peoples that they are entitled to the benefits derived from the principles and norms established for outer space and celestial bodies;

-- the need to link to the exploration and use of space and celestial bodies the exploitation thereof;

-- the search for profit, with an attempt to ensure its results;

-- equitable sharing of profits derived;

-- consideration of the needs and interests of developing countries;

-- supervision of this activity with a view to equitable distribution;

-- the institution of an international regime;

-- the establishment of appropriate procedures for such regime; and

-- the existence of international machinery or an international authority to give effect to all the expectations that have been voiced.[14]

The Soviet delegation has opposed the inclusion of the "common heritage" concept in the draft moon treaty because it provides in effect for common ownership of lunar resources, which conflicts with the Soviet position, first, that no property interest should be created prior to the time the minerals are extracted from the moon's surface or subsurface, and second, that upon extraction, beneficial ownership should vest in the entity undertaking the mining operation. The underlying rationale is that since the Outer Space Treaty forbids national appropriation, the term "heritage," which is essentially a property concept, should not be used in the moon treaty because it goes far beyond the "common province of all mankind" language sanctioned in the Outer Space Treaty.[15] Soviet commentators add that the movement to incorporate the concept into the law of the sea is a serious hindrance to the completion of moon treaty negotiations adoption because of the variances between national interests with respect to ocean resources and corresponding interests on the moon.[16]

Although the United States is opposed to incorporation of the concept into the moon treaty, it has not taken a strong stand against the "common heritage" concept.[17] The United States has taken the position that it will accept inclusion of the phrase only if it is defined as not carrying any expressed or implied prohibition of exploitation of the moon's natural resources.[18] The United States will support an equitable sharing of the benefits of such exploitation, but only if such sharing is defined as allowing expenses of the space program to be deducted before the benefits are shared. The United States bases this position in equity by reasoning that if it were otherwise, a nation would carry the financial burden of space exploration without offsetting this burden with the benefits.[19]

Other delegations including Hungary and Czechoslovakia, have taken a compromise position which would specifically provide that the main goal is to obtain the benefits of outer space for the benefit of all, but this will not be accomplished unless those countries carrying the expensive burden of space exploration are reimbursed with a certain degree of profit.[20]

At present the status of the concept under international law is subject to extensive debate.[21] Continued lack of opposition in the CPUOS negotiations is likely to combine with parallel developments in other areas, most notably the law of the sea, to permit evolution of the concept into a binding principle of international law. If the "common heritage" principle were applied generally to space industrial activities, private initiatives may never become economically viable.

C. *Desirability of Deferring Disposition of Lunar Resources*

As part of the position of potential space powers that restrictive principles should not be applied to lunar resources, it is argued that at present the technology and operational institutional arrangements are not sufficiently developed to permit effective policy planning, and that premature restriction of lunar development activities would defer or prevent realization of the benefits likely to be available from exploitation of lunar resources. This approach is paralleled by arguments primarily made by the United States in the context of the earth resources and direct broadcast satellite debates. Virtually all of the delegations concede that the establishment of legal principles governing the moon's natural resources may be premature because technology is not sufficiently advanced to provide a sound, practical basis for such principles.[22] Nonetheless, representatives from the developing countries have urged resolution of the lunar resources issue before it is complicated by investment and reliance interests are created.[28]

d. Desirability of Imposing a Moratorium on Lunar Development Pending Resolution of the Natural Resources Issue

As an element of the "common heritage" position, the developing nations want to impose a moratorium in regard to any development and exploitation of resources on the moon until an international arrangement is made, under which all countries will directly participate in or benefit from such development and exploitation.[24] In response to the prematurity arguments discussed above, the developing nations point to the paradox that at present it is too early to elaborate upon the space legal principle governing the moon and its exploitation because technology is not sufficiently advanced, and in the future it will be too late to do such elaboration because a de facto situation will already exist.[25] The solution to the dilemma, it is argued is a moratorium on development until appropriate policy guidelines are formulated.

The space powers and other industrialized nations maintain that such a moratorium would discourage any country from carrying on any program designed to investigate even the possibility of commercial use of lunar resources, and would eliminate any incentive for the development of the technology required for exploration and development. The practical effect would not be to encourage the next logical stage in lunar exploration or, if the scope of the treaty is broadened, in the exploration of other celestial bodies.[26] For that reason, the United States in particular is strongly opposed to any sort of moratorium. One U.S. commentator has argued that the moon treaty should be structured to promote rather than delay exploitation.[27] This comment is particularly incisive because it highlights a fundamental policy question referred to previously in the discussions of international direct broadcast and earth resources satellite policy; the choice between rapid operational implementation and full-scale international participation. The resolution of this question for each new technology or space activity will influence the viability of commercial entry.

2. *Scope of the Moon Treaty*

The second major unresolved issue centers upon the scope of the proposed treaty. On one hand, the original initiatives in this area were focused specifically on the moon. However, others have argued that the treaty should cover "the Moon and other celestial bodies" in accordance with the language of the 1967 Outer Space Treaty.[28] The former position is taken primarily by space powers who wish to avoid establishment of any restrictions on exploration of other celestial bodies, and the latter is taken by Argentina and the developing countries, which are attempting to establish the "common heritage" approach in as many new areas as possible. However, despite the divergent interests of the two blocs, resolution of the natural resources issue is likely to incorporate a solution for this issue as well. The most likely compromise will limit the express scope of the treaty to the moon, but permit arguments by analogy regarding the management of other celestial bodies until more specific international instruments are approved.

3. *Prior Information*

The final unresolved issue relating to the draft moon treaty concerns the nature and scope of information each state will be required to furnish prior to the commencement of lunar missions. The positions on this issue do not follow the divisions identified on the other two issues.

The Soviet delegation argues that states should not be required to provide prior information concerning their missions because the 1967 Outer Space Treaty already establishes appropriate criteria for the exchange of information, and anymore stringent requirement would require alteration of existing law and would amount to an attempt to interfere in the domestic affairs of each launching state. The latter contention is based on the notion that mandatory advance notification implicitly contains the right of other states to express protest.[29]

In contrast, the United States supports advance notification on the grounds that it would avoid duplication and stimulate scientific efforts.[30]

The developing nations support very thorough and wide ranging prior dissemination of information. India has even proposed in one of its working papers to the Legal Sub-Committees that all nations be obligated to share discoveries of natural resources (which is not currently required in the draft treaty).[31] The delegation from Bulgaria, which is one of the leading advocates of compromise on all three unresolved issues of the Draft Moon Treaty, suggests that the point in time to require all states to give information concerning moon missions is "as soon as possible after launching." Compromise on that basis appears possible which will develop on this issue.[32]

B. Prospects for Resolution of the Moon Treaty

In contrast to the CPUOS debates on direct broadcast and earth resource satellites, the United States and the Soviet Union have taken similar positions on the issues raised by the draft moon treaty, in particular on the key question of the disposition of lunar resources. Both of the major space powers, as well as a number of the states which are presently developing space capabilities have perceived their interests to be best served by postponing the resolution of the issue of the legal status of the natural resources of the moon, if agreement can only be based on a "common heritage" approach which deprive the space powers of a very valuable advantage with respect to the exploitation of those resources.

The developing nations have perceived delay to be contrary to their interests. They also are aware that their demand to include the "common heritage" language is one of the main impediments to establishment of an international consensus on principles to govern the exploration and exploitation of the moon's resources. As a result, some significant pressure to soften demands for incorporation of "common heritage" language is being exerted. However, since the less developed countries are seeking to establish "common heritage" regimes in a number of areas, including the deep seabed, they are unlikely to soften these demands to any significant degree. Consequently, rapid resolution of the CPUOS negotiations on the draft moon treaty is unlikely. In the absence of a major policy initiative proposing mutually agreeable resolution of a number of diverse issues, protracted negotiations may be anticipated. The United Nations conference on science and technology proposed for 1979 may provide a framework for such an initiative.

PART IV: CONCLUSIONS

The foregoing analysis raises a fundamental question relating to the extent to which and the conditions under which the private sector will be permitted to participate in the development of outer space. On one hand, in some cases in the United States the responsibility for operational implementation has been left to the private sector. The most significant example is the case of communications satellite technology. On the other hand, current trends are leading away from significant private sector participation. Consequently, the private sector should be concerned that its option to participate may be eroded.

Assumption by the private sector of responsibility for operational activities suggests a wide range of potential benefits for national interests. First, commercial enterprises are likely to promote institution and provision of full-scale, high quality operational services on a more timely and efficient basis than any of the other institutional alternatives. Second, commercial implementation would permit the federal government to focus its efforts on appropriate research and development activities. That approach gives rise to three advantages. First, the combination of government research and private sector implementation has proven highly effective in maximizing the realization of the potential benefits of technological development. Second, concentration of federal efforts on research and development will result in minimization of federal expenditures consistent with optimum technological development. Third, private sector implementation would make the system operation and service offerings responsive to marketplace demand rather than the congressional budgetary cycle, with concomitant positive implications for the quality and consistency of service.

Another advantage from private sector operation of mature systems is based on the positive effects for national economic development. Although any other institutional approach may promote economic development, commercial implementation is more likely to maximize the multiplier effects throughout the national economy.

These and other considerations suggest that private sector participation in space operations is desirable. Nonetheless, a number of trends suggest that national and international policy may be moving away from promotion of full-scale commercial involvement. On the national level, that tendency is evidenced, for example, by the legislative trends. In August 1976, Senator Moss introduced a bill to establish an operational earth resources satellite system based on private sector initiatives. In January of this year, Senator Ford introduced a related bill which removed the private sector mandate, allocating operational responsibility to NASA and to the Department of the Interior.

A number of parallel trends are apparent in the international arena. Even the cornerstone of international space law, the 1967 Outer Space Treaty, creates the foundation for limitation of private sector involvement. Article I(1) is said to require space activities to be carried out "for the benefit and in the interests of all countries." If any operative effect is given to that phrase, it could diminish the viability of commercial ventures. Similarly, Articles VI and VII of the Outer Space Treaty, as well as the Convention on International Liability for Damage Caused by Space Objects contain provisions which potentially require relatively restrictive governmental supervision of national -- including commercial -- space operations. Supervision is likely to entail regulation and resultant limitation of operational flexibility.

Of course, the treaty's provisions as interpreted by the United States are not completely negative. For example, Article II arguably does not inhibit appropriation of outer space or portions of celestial bodies by private enterprises. However, this construction is not universal. As noted in Section III of Part III above, the Soviets interpret Article II to prohibit appropriation by any entity, including commercial entities. In addition, a number of current trends suggest that private sector involvement in the implementation of new space technologies will not be encouraged. First, negotiations presently underway generally do not take private sectors interests sufficiently into account. In addition to actions relating to the adoption of the potentially restrictive principles discussed above in Sections I-III of Part III, specific efforts have been made to preclude private sector participation in both direct broadcasting and satellite remote sensing. The reasons for these tendencies appear to be threefold. First, the negotiations are conducted between governments, and most delegations do not have national private sector interests in space development to protect, and as a result, advocate policies which protect national interests rather than promote commercial development. Second, negative attitudes toward international commercial ventures motivates even space powers to place concern regarding international repercussions above national commercial interests. Finally, private sector interest in participating in operational space activities has been somewhat understated, possibly because of the low level of market development.

The lack of emphasis on private sector interests in international negotiations is complicated by the demands of less developed countries to treat space and other resources as the "common heritage of mankind." The trend toward mandatory licensing of activities relating to the exploitation of seabed resources may be extended to the moon and other celestial bodies. The allocation of geostationary orbital slots by the ITU according to an *a priori* plan rather than actual use is another indication of the trend in this direction.

Paralleling the evolution of the "common heritage" concept is a tendency toward international policies mandating international participation and sharing. At present, the trend is evident in proposals relating to direct broadcast and earth resources satellite activities. The "common heritage" approach to disposition of lunar resources is conceptually similar. This trend could lead eventually to sharing of facilities, space vehicles, products, and perhaps even profits of space ventures. Private sector participation could be jeopardized by any of those results.

Although there is ample evidence to support the existence of these tendencies, their strength should not be overestimated. First, the current series of CPUOS negotiations has been in progress for a number of years, and final resolution of outstanding issues is not expected for some time. Until those negotiations are completed, direct impact on space activities is likely to be somewhat limited. Second, as institution of operational services becomes imminent, some shifts away from restrictive political positions toward more practical, results-oriented approaches may occur. Consequently, the trends described above are likely to be reversible under appropriate conditions. From the perspective of the private sector, a thorough evaluation of this possibility appears desirable, in light of the possibility that advances in space technology may create attractive business opportunities.

To maximize effectiveness, the suggested approach should focus on the development of an ability to respond to legal, institutional and policy developments which will either affect particular space industrial activities directly or create precedents which will influence future policy decisions. Since space services are likely to affect both national and international interests, the scope of this approach should encompass both sets of considerations. In addition to the international deliberations described in the present memoradnum which are likely to influence the nature and scope of international activity, national policymaking activities are currently underway, especially in the earth resources and direct broadcast areas, which are likely to affect private sector interests in a number of space industrial activities. The most significant example is the legislation introduced in the Senate to establish an operational earth resources satellite system. In order to preserve its option to participate in the development of outer space, the private sector should develop the ability to respond to significant initiatives or trends.

This response cabability should be based on adequate information. Consequently, effective monitoring activities are considered desirable. The objectives of those activities should be to identify:

1. significant interests affected by each category of space industrial activity;
2. main actors, both institutions and individuals;
3. main policy considerations; and
4. key decision points.

To achieve the necessary level of effectiveness, monitoring should be conducted on a systematic, on-going basis.

However, a systematic approach is difficult because of the broad array of material considerations. Consequently, a means of selecting monitoring activities to provide both manageability and accuracy must be developed. There are management tools which permit a comprehensive view of the process of developing a technology from initial experimentation through operational implementation. Such a framework could facilitate identification of key activities and trends and could provide the basis for anticipating and responding to developments relevant to future space industrial efforts.

FOOTNOTES

PART 1: THE CONCEPT OF SPACE INDUSTRIALIZATION

1. For a discussion of the NASA communication satellite experimentation, see generally D. Smith, Communication Satellite User Experimentation: A Technology in Transition (to be published in 1977).

2. See Sections I.A and I.B. in Part II below.

3. See, e.g., Environmental Research Institute of Michigan, Proceedings of the International Symposia on Remote Sensing of the Environment (1975 and preceding years); Proceedings of the NASA Earth Resources Survey Symposium, Houston, Texas (June, 1975); NASA, Office of Applications, The Space Applications Program 1974 Ch. 3; National Academy of Sciences, National Research Council, Resource and Environmental Surveys from Space with the Thematic Mapper in the 1980s (1976); General Electric Space Division, Definition of the Total Earth Resources System for the Shuttle Era (NASA Contract NAS 9-13401) (March 1975).

4. For a more complete listing of potential products, see, e.g., National Academy of Sciences, Space Applications Board, Practical Applications of Space Systems, Supporting Paper No. 9, "Materials Processing in Space" (1975); "NASA Seeks Industry Space Processors," Aviation Week and Space Technology, January 26, 1975, at 46-61.

PART II: INTERNATIONAL AGREEMENTS APPLICABLE TO SPACE INDUSTRIALIZATION

1. Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, January 27, 1967, [1967] 18 U.S.T. 2410, T.I.A.S. 634, 610 U.N.T.S. 205, entered into force for the United States on October 10, 1967 [hereinafter referred to as the Outer Space Treaty]. The materials in Part II are adapted in part from D. D. Smith, "The Status of Solar Power Systems under International Space Law," March 9, 1977.

2. Convention on International Liability for Damage Caused by Space Objects, March 29, 1972, 24 U.S.T. 2389, T.I.A.S. 7762, entered into force for the United States on October 9, 1973.

I. TREATY ON PRINCIPLES GOVERNING THE ACTIVITIES OF STATES IN THE EXPLORATION AND USE OF OUTER SPACE, INCLUDING THE MOON AND OTHER CELESTIAL BODIES

1. See the discussion of the "peaceful uses" requirement below the text of the present section accompanying footnotes in Section I.A.2.

2. M. Markoff, Disarmament and "Peaceful Purposes" Provisions in the 1967 Outer Space Treaty, 4 Journal of Space Law 3, 12 (1976).

3. P. Dembling and D. Arons, The Evolution of the Outer Space Treaty, 33 Journal of Air Law and Commerce 419, 429-30 (1967), and authority cited there.

4. Markoff, supra note 2, at 13-14; M. Markov, Implementing the Contractual Obligation of Art. I, Par. 1 of the Outer Space Treaty of 1967, in Proceedings of the Seventeenth Colloquium on the Law of Outer Space 136, 137 (1976); M. Dauses, The Relative Autonomy of Space Law, in Proceedings of the Eighteenth Colloquium on the Law of Outer Space 75, 79 (1976).

5. See E. Fasan, Utilization of Energy From Space -- Some Legal Questions, in Proceedings of the Eighteenth Colloquium on the Law of Outer Space 2, 3 (1976).

6. M. Markov, Implementing the Contractual Obligation of Art. I, Par. 1 of the Outer Space Treaty of 1967, in Proceedings of the Seventeenth Colloquium on the Law of Outer Space 136, 137-138 (1975).

7. See, e.g., Treaty on Remote Sensing of Natural Resources by Means of Space Technology: Draft Basic Articles, Submitted jointly by Argentina and Brazil, U.N. Doc. A/C.1/1047 (1974), arts. VII, VIII, XI and XII; Working Paper Submitted by France to the Second Session of the Working Group on Direct Broadcast Satellites, U.N. Doc. A/AC.105/62, June 30, 1969.

8. See, e.g., Markov, supra note 6, at 137-38.

9. See Revised Single Negotiating Text, Third United Nations Conference on the Law of the Sea (1976), Part I.

10. See the discussion of the direct broadcast satellite controversy in the United Nations in Part III, Section I, below.

11. See the discussion of the earth resources satellite controversy in the United Nations in Part III, Section II, below.

12. E.g., M. Markoff, Disarmament and "Peaceful Purposes" Provisions in the 1967 Outer Space Treaty, 4 Journal of Space Law 3-22 (1976); M. Markoff, Implementing the Contractual Obligation of Art. I, Par. 1 of the Outer Space Treaty of 1967, in Proceedings of the Seventeenth Colloquium on the Law of Outer Space 136, 139 (1975); M. Niciu, What is the Meaning of the Use of Cosmos Exclusively for Peaceful Purposes, in id., at 224, 228.

13. The validity of this assumption is central to the subject matter of Section I.D. below and is examined more fully there.

14. See, e.g., Markoff, supra note 12, at 6-8; M. Dauses, The Relative Autonomy of Space Law, in Proceedings of the Eighteenth Colloquium on the Law of Outer Space 75, 78-79 (1976).

15. See authorities cited in footnote 12.

16. Markoff, supra note 12, at 21.

17. See id., at 11.

18. Niciu, supra note 12, at 299.

19. Markoff, _supra_ note 12, at 10.

20. _Id._, at 7.

21. _Id._

22. The Treaty Prohibiting the Placing of Any Nuclear and Other Kinds of Weapons of Mass Destruction on the Sea and Ocean Bed as well as in Their Subsoils, adopted in U.N.G.A. Resol. 2660 (XXV) on December 7, 1970, establishes the principle that certain areas shall be used exclusively for peaceful purposes.

Article 2 of the United Nations Convention on the High Seas, [1962] 13 U.S.T. 2312, T.I.A.S. No. 5200, 45 U.N.T.S. 72 (in force September 30, 1964), lists four specific freedoms of the high seas and continues:

> These freedoms, and others which are recognized by the general principles of international law, shall be exercised by all states with reasonable regard to the interests of other states in their exercise of freedom of the high seas.

The right to mine the seabed of the high seas is one of those "other" freedoms. In its 1950 and 1951 Reports, the International Law Commission specifically listed mineral exploitation as one of the freedoms of the sea. _See_ Laylin's comment in "Discussion," _The Law of The Sea, Needs and Interests of Developing Countries_ 51 (L. Alexander ed. 1972). Although it was not specifically listed in later drafts, there is no evidence that the Commission rejected the concept as a high seas freedom. For that reason, mineral exploitation must be considered one of the "other" freedoms. Moreover, the High Seas Convention itself implicitly recognized the right to exploit the seabed when it provides for preventing pollution from such activity. Article 24 states: "Every state shall draw up regulations to prevent pollution of the seas * * * resulting from the exploitation and exploration of the sea-bed and its subsoil * * *."

23. The legality of placing such installations or weapons systems in orbit is considered below in Section I.D.

24. _See, e.g._, B. Dudakov, International Legal Problems in the Use of the Geostationary Orbit, in _Proceedings of the Fifteenth Colloquium on the Law of Outer Space_ 71 (1973).

25. G. Reintanz, Some Remarks on Space Activities Which May Have Harmful Effects on the Environment, in _Proceedings of the Fifteenth Colloquium on the Law of Outer Space_ 277, 278 (1973); B. Dudakov, International Legal Problems in the Use of the Geostationary Orbit, in _id._, at 71-72.

26. S. Gorove, Interpreting Article II of the Outer Space Treaty, 37 Fordham Law Review 349 (1969). Professor Gorove adds a fourth issue relevant to general interpretation, namely whether any exercise of sovereign authority, use or occupation is permissible despite the prohibition of Article II. Id.

27. Dembling and Arons, supra note 3, at 431; E. Galloway, The Future of Space Law, in Proceedings of the Nineteenth Colloquium on the Law of Outer Space 2, 3 (1977).

28. Gorove, supra note 26, at 350.

29. The question of the applicability of Article II to the extraction of minerals is discussed further in Section III of Part III below.

30. Projected dimensions range from 11.73 kilometers in length and 4.33 kilometers in width, AIAA Technical Committee on Electric Power Systems, Solar Energy for Earth: An AIAA Assessment 61 (1975), to 18.41 kilometers by 7.01 kilometers, G. F. von Thiesenhausen, Photovoltaic and Thermal Energy Conversion for Solar Powered Satellites, International Astronautical Federation Paper No. IAF-76-117 (1976), at 3.

31. See, e.g., Convention on the Continental Shelf, 499 U.N.T.S. 311 (1964), art. 5(3).

32. Gorove, supra note 26, at 352.

33. E.g., W. von Kries, Legal Status of the Geostationary Orbit, in Proceedings of the Eighteenth Colloquium on the Law of Outer Space 27, 30 (1976).

34. Dudakov, supra note 25, at 71; Comment, Utilization of the Geostationary Orbit -- A need for Orbital Allocation, 13 Columbia Journal of Transnational Law 98, 100-101 (1974).

35. E.g., G. Hazelrigg, The Economic Viability of Pursuing a Space Power System Concept, American Institute of Aeronautics and Astronautics Paper No. 77-353 (1977) at 1; Peter E. Glaser, Perspectives on Satellite Solar Power, American Institute of Astronautics and Aeronautics Paper No. 72-352 (1977), at 11 (hereinafter cited as Glaser, Perspectives].

36. Gorove, supra note 26, at 351.

37. Gorove, The Outer Space Treaty, 23 Bulletin of Atomic Scientists 44, 45 (1967).

38. W. Jenks, *Space Law* 201 (1965).

39. Gorove, *supra* note 26, at 351-52.

40. United Nations Charter, art. 51.

41. Q. Wright, Legality of Intervention under the United Nations Charter, *1957 Proceedings of the American Society of International Law* 79, 82-83; J. Brierly, *Law of Nations* 415 (6th ed. 1963); Oppenheim, 2 *International Law* 15 (H. Lauterpacht, ed., 7th ed. 1952).

42. W. Friedman, Intervention, Civil War and the Role of International Law, 1965 *Proceedings of the American Society of International Law* 69; Roling, International Law and the Maintenance of Peace, 4 *Netherlands Yearbook of International Law* 1 (1973); H. Lauterpacht, The Boycott in International Relations, 14 *British Yearbook of International Law* 125, 130, 139 (1933); Hyde, 2 *International Law, Chiefly as Interpreted and Applied by the United States*, 185-86 (1965).

43. *E.g.*, Glaser Perspectives, *supra* note 35, at 8.

44. *E.g.*, *id.*, a 3.

45. *E.g.*, AIAA Technical Committee on Elective Power Systems, *Solar Energy for Earth: An AIAA Assessment* 69 (1975).

46. Article V of the 1967 Outer Space Treaty relating to the rescue and return of astronauts is not directly relevant to the consideration of legal aspects of space industrialization.

47. P. Dembling and D. Arons, The Evolution of the Outer Space Treaty, 33 *Journal of Air Law and Commerce* 419, 436 (1967).

48. *Id.*, at 437.

49. S. Estrade, The Utilization of Space as a Source of Energy for the Earth, in *Proceedings of the Eighteenth Colloquium on the Law of Outer Space* 7, 11 (1976).

50. Convention on International Liability for Damage Caused by Space Objects, March 29, 1972, 24 U.S.T. 2389, T.I.A.S. 7762, entered into force for the United States on October 9, 1973. For a discussion of the impact that the Liability Convention is likely to exert on space industrialization, *see* Section II of Part II below.

51. See, e.g., Glaser, Perspectives, sup note 35, at 8-10; AIAA Technical Committee on Electric Power Systems, supra note 30, at 69.

52. Dudakov, supra note 25, at 71-72.

53. Dembling and Arons, supra note 47, at 441.

54. For a discussion of the scope and content of the consultation provisions, see, e.g., J. Sztucki, International Consultations and Space Treaties, in Proceedings of the Eighteenth Colloquium on the Law of Outer Space 166-200 (1976); I. Herczeg, Provisions of the Space Treaties on Consultation, in Proceedings of the Seventeenth Colloquium on the Law of Outer Space 141-146 (1975).

55. Dembling and Arons, supra note 47, at 441.

56. See Section I.A.1. above.

57. See the text accompanying footnote 51.

58. J. Sztucki, International Consultations and Space Treaties, in Proceedings of the Eighteenth Colloquium on the Law of Outer Space 166, 180 (1976).

59. Id., at 183.

60. Id., at 177.

61. Id.

62. E.g., id., at 169, 174.

63. Id., at 184. However, when consultations fail to achieve the desired results, resort to the provisions of Chapter 6 of the United Nations Charter may be appropriate. I. Herczeg, Provisions of the Space Treaties on Consultation, in Proceedings of the Seventeenth Colloquium on the Law of Outer Space 141, 145 (1975).

64. Sztucki, supra note 58, at 183.

65. Herczeg, supra note 63, at 143.

II. CONVENTION ON INTERNATIONAL LIABILITY FOR DAMAGE CAUSED BY SPACE OBJECTS

1. For a summary of the CPUOS activities in relation to the Convention, see Senate Committee on Aeronautical and Space Sciences, Convention on International Liability for Damage Caused by Space Objects: Analysis and Background Data 92d Cong., 2d Sess., 8-10 (1972) (hereinafter cited as Senate Committee Report).

2. Convention on International Liability for Damage Caused by Space Objects, March 29, 1972, 24 U.S.T. 2389, T.I.A.S. 7762 (hereinafter referred to as Liability Convention).

3. Senate Committee Report, supra note 1, at 23-24.

4. See, e.g., Glaser, Perspectives, supra note 1, at 8-10; AIAA Technical Committee on Electric Power Systems, Solar Energy for Earth: An AIAA Assessment 69 (1975); P. Sand, Space Programs and International Environment Protection, in Proceedings of the Fourteenth Colloquim on the Law of Outer Space 79, 80-85 (1972); F. Zwicky, Examples of Activities in Extraterrestrial Space Which Might be Judged Harmful, Harmless, Useful or Either One of These, Depending on the Viewpoint, in Proceedings of the Fifteenth Colloquium on the Law of Outer Space 259-266 (1973); I.H. Diederiks-Verschoor, The Legal Aspects of Space Activities with Potentially Harmful Effects on the Earth and Space Environments, in id., at 268, 269-71.

5. See, e.g., S. Gorove, Some Comments on the Convention on International Liability for Damage Caused by Space Objects, in Proceedings of the Sixteenth Colloquium on the Law of Outer Space 253 (1974); J. Rajski, Convention on International Liability for Damage Caused by Space Objects -- An Important Step in the Development of the International Space Law, in Proceedings of the Seventeenth Colloquium on the Law of Outer Space 245 (1975).

6. Gorove, supra note 5, at 253.

7. Id., at 253-54.

8. See Section II.B. below.

9. See I. Diederiks-Verschoor, The Convention on International Liability Caused by Space Objects, in Proceedings of the Fifteenth Colloquium on the Law of Outer Space 96, 97 (1973).

10. Senate Committee Report, _supra_ note 1, at 25.

11. Diederiks-Verschoor, _supra_ note 9, at 97.

12. Senate Committee Report, _supra_ note 1, at 25.

13. Under the absolute liability approach, the demonstration of those elements by a preponderance of the credible evidence would be sufficient to establish liability. However, the question has been raised whether a simple allegation or the relative probability of the existence of a causal relationship is sufficient. _See, e.g._, I. Herczeg, Some Problems of the Convention on Liability Arising from Space Activities, in _Proceedings of the Fifteenth Colloquium on the Law of Outer Space_ 111, 112 (1973).

14. Diederiks-Verschoor, _supra_ note 9, at 97.

15. Senate Committee Report, _supra_ note 1, at 26; I. Herczeg, _supra_ note 13, at 113.

16. N. Poucantzas, Some Remarks on the Convention on International Liability Caused by Space Objects, in _Proceedings of the Fifteenth Colloquium on the Law of Outer Space_ 130, 131 (1973).

17. Senate Committee Report, _supra_ note 1, at 27.

18. _Id._, at 27-28.

19. Herczeg, _supra_ note 13, at 113.

20. Senate Committee Report, _supra_ note 1, at 29.

21. Rajski, _supra_ note 5, at 250.

22. _Senate Committee Report_, _supra_ note 1, at 31.

23. Diederiks-Verschoor, _supra_ note 9, at 101.

24. _E.g._, W. W. Bishop, _International Law_ 631 (1962) and authorities cited there in note 12; M. Sorensen, ed., _Manual of Public International Law_ 575 (1968).

25. _E.g._, Sorensen, _supra_ note 24, at 582-84.

III. INTERNATIONAL TELECOMMUNICATION CONVENTION AND ITU RADIO REGULATIONS

1. International Telecommunication Convention (Torremolinos-Malaga 1973), entered into force, January 1, 1975.

2. The Convention and Radio Regulations also play a significant role in the allocation of the electromagnetic spectrum and would therefore affect the communications activities related to the industrialization of outer space. However, the effect of the Convention and Radio Regulations on communications is beyond the scope of the present memorandum.

3. See Sections I.A., I.B., and I.H. in Part II above.

4. J. Busak, Geostationary Satellites and the Law, 39 Telecommunications Journal 487 (1972) and authority cited there.

5. See, e.g., Comment, Utilization of the Geostationary Orbit -- A Need for Orbital Allocation, 13 Columbia Journal of Transnational Law 98, 103n. 30 (1974).

6. For an excellent discussion of the characteristics, capacity and technical considerations affecting the use of the geostationary orbit, see J. Gehrig, Geostationary Orbit -- Technology and Law, in Proceedings of the Nineteenth Colloquium on the Law of Outer Space 267, 268-272 (1977).

7. See Partial Revision of the Radio Regulations, Geneva, 1959, Nov. 8, 1963, [1964] 1 U.S.T. 887, T.I.A.S. No. 5603.

8. Comment, supra note 5, at 101; and Partial Revision of the Radio Regulations, supra note 7, arts. 5, 9A.

9. E. Valters, Perspectives in the Emerging Law of Satellite Communications, 5 Stanford Journal of International Studies 53, 76-77 (1970).

10. Comment, supra note 5, at 102.

11. Id., at 104.

12. Id., at 107. For a summary record of the 1971 WARC-ST, see "The World Administrative Radio Conference for Space Telecommunications," 38 Telecommunications Journal 673-82 (1971).

13. In its revised form, Article 9A provided:

> Section I. Procedure for the Advance Publication of Information on Planned Satellites Systems
>
> (1) An administration (or one acting on behalf of a group of named administrations) which intends to establish a satellite system shall, prior to the co-ordination procedure in accordance with No. 639 AJ where applicable, send to the International Frequency Registration Board not earlier than five years before the date of bringing into service each satellite network of the planned system, the information listed in Appendix 1B.
>
> Section II. Co-ordination Procedures to be Applied in Appropriate Cases
>
> (1) Before an administration notifies to the Board or brings into use any frequency assignment to a space station on a geostationary satellite or to an earth station that is to communicate with a space station on a geostationary satellite, it shall effect co-ordination of the assignment with any other administration whose assignment in the same band for a space station on a geostationary satellite or for an earth station that communicates with a space station on a geostationary satellite is recorded in the Master Register, or has been co-ordinated or is being co-ordinated under the provisions of this paragraph. For this purpose, the administration requesting co-ordination shall send to any other such administration the information listed in Appendix 1A.

Final Acts of the World Administrative Radio Conference for Space Telecommunications, Geneva, 1971.

14. Regarding the role of the ITU and the IFRB in the management of the radio spectrum, see Comment, The Role of the International Telecommunications Union in the Settlement of Harmful Interference Disputes, 13 Columbia Journal of Transnational Law 82-97 (1974); D. Smith, International Telecommunication Control 29-35 (1969); D. Leive, Regulating the Use of the Radio Spectrum, 5 Stanford Journal of International Studies 21, 26-39 (1970).

15. Busak, supra note 4, at 480.

16. Gehrig, supra note 6, at 273.

17. See Busak, supra note 4, at 489.

18. Comment, supra note 5, at 107.

19. Comment, supra note 5, at 103 n. 33.

20. W. von Kries, Legal Status of the Geostationary Orbit, in Proceedings of the Eighteenth Colloquium on the Law of Outer Space 27, 33 (1976).

21. The agenda for the WARC-BS is reported in "Broadcasting Satellite Conference," 43 Telecommunications Journal 703 (1976); see also ITU Broadcasting Satellite Conference, Document No. 181-E submitted by Austrialia, January 31, 1977, at 1.

22. U.N. Doc. A/C.1/PV.2049, October 13, 1975, at 43-46.

23. See ITU Broadcasting Satellite Conference Paper No. 229-E submitted by Ecuador, February 4, 1977, at 1.

24. "Meeting of the CCIR Study Groups Joint Working Party for the 1977 WARC-BS (12 GHz Band), 43 Telecommunications Journal 613, 614 (1976).

25. Id.

26. "WARC: it appears 'basic interest' was protected," Broadcasting, February 21, 1977, at 71-72.

27. The agenda of any WARC may be changed in accordance with Nos. 219-221 of the International Telecommunication Convention.

28. "31st Session of ITU Administrative Council," 43 Telecommunication Journal 565 (1976).

29. See the text accompanying notes 13-14 above.

30. For a comprehensive discussion of these experiments, see D. Smith, Communication Satellite User Experimentation: A Technology in Transition Chs. 8 and 9 (to be published in 1977).

31. See, e.g., "NASA Administrator and Japanese space officials meet," 42 Telecommunications Journal 48 (1975); "Japan Satcom design contract," in id., at 363.

32. A. Wheelon, "How Worldwide Communication Satellite Services Will Expand in Next Decade," Communication News, January 1976, at 16.

33. Id., at 17.

34. Id.

PART III FOOTNOTES

I. IMPLICATIONS OF THE CPUOS DEBATES ON DIRECT SATELLITE BROADCASTING FOR SPACE INDUSTRIALIZATION

1. For a comprehensive discussion of the ATS and CTS programs, see, D. Smith, Communication Satellite User Experimentation: A Technology in Transition Chs. 3-9 (to be published in 1977). The materials in Part III are adapted in part from D. Smith, Communication Via Satellite: A Vision in Retrospect (1976) Ch. 9.

2. American Society of International Law, Panel on International Telecommunications Policy, Direct Broadcasting from Satellites: Policies and Problems 9 (1974).

3. G.A. Res. 2453 (B), 23 U.N. GAOR Supp. 18, at 10-11, U.N. Doc. A/7218 (1968). For a history of the CPUOS direct broadcast debates, see D. Smith, Communications Via Satellite: A Vision in Retrospect Ch. 8 (1976). Excerpts of that chapter are used here by permission of A.W. Sijthoff Company.

4. U.S.S.R., "Draft Convention on Principles Governing the Use by States of Artificial Earth Satellites for Direct Television Broadcasting," reprinted in U.N., General Assembly, Report of the Working Group on Direct Broadcast Satellites on the Work of its Fourth Session, U.N. Doc. A/AC.105/117 (1973), Annex III (hereinafter cited as Fourth Working Group Report).

5. U.N. General Assembly, Minister for Foreign Affairs of the U.S.S.R., Request for the Inclusion of a Supplementary Item in the Agenda of the Twenty-Seventh Session, U.N. Doc. A/8771 (1972), at 1-2.

6. Soviet Draft Convention, Fourth Working Group Report, supra note 4, Art. V.

7. Id., Art. III.

8. Id., Art. IX.

9. U.N. General Assembly, Minister for Foreign Affairs of the U.S.S.R., Request for the Inclusion of a Supplementary Item in the Agenda, supra note 5, at 2.

10. K. Queeney, "An Analysis of the Role of the United Nations in the Formulation of Principles Governing Direct Broadcast Satellites," Unpublished Ph.D. dissertation, Ohio University, March 1975, at 195.

11. G.A. Res. 2916, 27 U.N. GAOR Supp. 30, at 14, U.N. Doc. A/8730 (1972).

12. U.S.S.R., "Principles Governing the Use by States of Artificial Earth Satellites for Direct Television Broadcasting," reprinted in U.N. General Assembly, Report of the Working Group on Direct Broadcast Satellites on the Work of its Fifth Session, U.N. Doc. A/AC.105/127 (1974), Annex II.

13. The text of Article VI is reproduced in the text following footnote 46.

14. Soviet Draft Declaration of Principles, supra note 72, Art. VIII(2).

15. Compare Art. V of the Soviet Draft Convention, U.N., supra note 44, Annex III, with Art. V of the Soviet Draft Declaration of Principles, supra note 72, Annex II.

16. See the text accompanying footnotes 8-10.

17. Soviet Draft Declaration, supra note 12, Art. IX(1).

18. Swedish-Canadian "Draft Principles Governing Direct Television Broadcasting by Satellite," in Fourth Working Group Report, supra note 4, Annex IV.

19. Id., Art. V.

20. Id., Art. VIII.

21. Compare Soviet Draft Convention, Fourth Working Group Report, supra note 4, Art. VI, with the Swedish-Canadian Draft Principles, id., Annex IV, Art. VIII.

22. Id., Art. VI.

23. Id., Art. X.

24. The United States of America, "Draft Principles on Direct Broadcast Satellites," U.N. Doc. A/AC.105/WG.3(V)/CRP.2 (March 1974), reprinted in U.N. General Assembly, Report of the Working Group on Direct Broadcast Satellites on the Work of its Fifth Session, supra note 12, Annex IV.

25. Id., Arts. I and II.

26. Id., Arts. III and IV.

27. Id., Art. IV.

28. Id., Art. V.

29. Id., Arts. VI-IX.

30. Id., Art. X.

31. Id., Art. XI.

32. Fifth Working Group Report, supra note 12, at 10.

33. Id.

34. U.N. General Assembly, Report of the Legal Sub-Committee Report on the Work of its Fourteenth Session, U.N. Doc. A/AC.105/147 (1975), Annex II, at 1-2 (hereinafter cited as Fourteenth Legal Sub-Committee Report).

35. U.N. General Assembly, Report of the Legal Sub-Committee on the Work of its Fifteenth Session, U.N. Doc. A/AC.105/171 (1976), Annex II, at 1 (hereinafter cited as Fifteenth Legal Sub-Committee Report).

36. Fourteenth Legal Sub-Committee Report, supra note 34, Annex II, at 2.

37. Id.

38. Id.

39. Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, January 27, 1967, [1967] 18 U.S.T. 2410, T.I.A.S. 634, 610 U.N.T.S. 205, entered into force for the United States on October 10, 1967.

40. Fifteenth Legal Sub-Committee Report, supra note 35, Annex II, at 1-2.

41. Id., at 2.

42. Fifth Working Group Report, supra note 12, at 11.

43. Id.

44. Fourteenth Legal Sub-Committee Report, supra note 34, Annex II, at 2.

45. See "Model General Principles for the Use of Artificial Earth Satellites for Radio and Television Broadcasting," U.N. General Assembly, Report of the Working Group on Direct Broadcast Satellites on the Work of its Third Session, U.N. Doc. A/AC.105/83 (1970), Annex IV, at 27. 1972 Soviet Draft Convention, supra note 4, Art. XII: "Principles Governing the Use of States of Artificial Earth Satellites for Direct Television Broadcasting," Fifth Working Group Report, supra note 12, Annex II, Art. VII.

46. Fourteenth Legal Sub-Committee Report, supra note 34, Annex II, at 2.

47. Fifteenth Legal Sub-Committee Report, supra note 35, Annex II, at 2.

48. Fifth Working Group Report, supra note 12, at 11.

49. Fourteenth Legal Sub-Committee Report, supra note 34, Annex II, at 3.

50. Fifteenth Legal Sub-Committee Report, supra note 35, Annex II, at 2.

51. Fifth Working Group Report, supra note 12, at 13. Art. VI of the Outer Space Treaty provides:

> States Parties to the Treaty shall bear international responsibility for national activities in outer space, including the moon and other celestial bodies, whether such activities are carried on by governmental agencies or by non-governmental entities, and for assuring that national activities are carried out in conformity with the provisions set forth in the present Treaty. The activities of non-governmental entities in outer space, including the moon and other celestial bodies, shall require authorization and continuing supervision by the State concerned. When activities are carried on in outer space, including the moon and other celestial bodies, by an international organization, responsibility for compliance with this Treaty shall be borne both by the international organization and by the States Parties to the Treaty participating in such organization.

52. Id., at 13. Consensus was also reached on the need to resolve disputes through established international procedures. Id., at 19.

53. Fourteenth Legal Sub-Committee Report, supra note 34, Annex II, at 3.

54. Id.

55. Fifteenth Legal Sub-Committee Report, supra note 35, Annex II, at 2.

56. Fourteenth Legal Sub-Committee Report, supra note 34, Annex II, at 5.

57. Fifteenth Legal Sub-Committee Report, supra note 35, Annex II, at 2.

58. Fifth Working Group Report, supra note 12, at 13-14.

59. Id., at 13. See also the text accompanying notes 41-43.

60. Id., at 14.

61. Id., at 14-15. Article 19 of the Universal Declaration of Human Rights provides:

> Everyone has the right to freedom of opinion and expression; this right includes freedom to hold opinions without interference and to seek, receive and impart information and ideas through any media and regardless of frontiers.

62. Id., at 15.

63. Fourteenth Legal Sub-Committee Report, supra note 34, Annex II, at 3.

64. Fourth Working Group Report, supra note 4, Annex IV, at 1-4.

65. Fourteenth Legal Sub-Committee Report, supra note 34, Annex II, at 3-4.

66. Id., at 4.

67. Id., Annex II, at 3-4; Fifteenth Legal Sub-Committee Report, supra note 35, Annex II, at 3-4.

68. Fifth Working Group Report, supra note 12, at 16.

69. Fourteenth Legal Sub-Committee Report, supra note 34, Annex II, at 4.

70. Id.

71. See, e.g., Fourteenth Legal Sub-Committee Report, supra note 34, Annex II, at 4.

72. Fifteenth Legal Sub-Committee Report, supra note 35, Annex II, at 3.

73. Fifth Working Group Report, supra note 12, at 17.

74. Compare the listing in ibid., with Arts. IV and VI of the Soviet Draft Convention, U.N. General Assembly, Fourth Working Group Report, supra note 44, Annex III, and with Art. IV of the Soviet Draft Declaration of Principles, U.N. General Assembly, Fifth Working Group Report, supra note 12, Annex II.

75. Fifth Working Group Report, supra note 12, at 17.

76. Id.

77. Fourteenth Legal Sub-Committee Report, supra note 34, Annex II, at 4.

78. Id.

79. Fifth Working Group Report, supra note 12, at 18.

80. Id.

81. Id.

82. Fifteenth Legal Sub-Committee Report, supra note 35, Annex II, at 4.

83. Compare Fourteenth Legal Sub-Committee Report, supra note 34, Annex II, at 4-5, with Soviet Draft Principles, Fifth Working Group Report, supra note 12, Annex II, at 2, Art. VI.

84. Fourteenth Legal Sub-Committee Report, supra note 34, Annex II, at 4-5.

85. Compare id., at 5, with Soviet Draft Principles, in Fifth Working Group Report, supra note 12, Annex II, Art. IX(1). Article 33 of the United Nations Charter calls upon nations to employ "negotiations, enquiry, mediation, conciliation, arbitration, judicial settlement, resort to regional agencies or arrangements, . . . " before any other.

86. For a discussion of the ATS 1, 3, 5 and 6 experiments, see D. Smith, Communication Satellite User Experimentation: A Technology in Transition Chs. 3-7, 9 (to be published in 1977).

87. For a more complete discussion of the SITE experiments see id., Ch. VII.

88. U.N., Committee on the Peaceful Uses of Outer Space, Report of the United Nations Panel Meeting on Satellite Broadcasting Systems for Education, U.N. Doc. A/AC.105/128 (1974), Annex I, at 3 (hereinafter cited at U.N. Panel Report).

89. Id., at 5.

90. Id., at 4, and Annex I, at 1.

91. Id., Annex I, at 1-2.

92. Id., at 9-10.

93. U.N. General Assembly, Report of the Working Group on Direct Broadcast Satellites on the Work of its First Session, U.N. Doc. A/AC.105/51 (1969), para. 9[a] (hereinafter cited as First Working Group Report).

94. Ithiel de Sola Pool, "The Satellite Broadcast Controversy," M.I.T.: A Report for the Center for International Studies (1974), at 26.

95. ASIL Direct Broadcasting from Satellites, supra note 2, at 5.

96. See the "Memorandum of Understanding Between the Department of Atomic Energy of the Government of India and the United States National Aeronautics and Space Administration," 18 September 1969, para. 3.2.

97. U.N. Panel Report, supra note 88, at 19.

98. Id.

99. Id., at 20.

100. Comment of Nandasiri Jasentuliyana, in Panel Discussion, "Direct Satellite Broadcasting and the Third World," 13 Columbia Journal of Transnational Law 68 (1974).

101. First Working Group Report, supra note 93, para. 8.

102. The frequencies allocated range from 620 MHz to 86 GHz, and standard UHF television transmissions occur in the 450 MHz to 900 MHz range. See "The World Administrative Radio Conference for Space Telecommunications," 38 Telecommunications Journal, 678-79 (1971); see also A. Chayes, and L. Chazen, "Policy Problems in Direct Broadcasting from Satellites," 5 Stanford Journal of International Studies 10 (1970).

103. See D. Smith, Communications Via Satellite: A Vision in Retrospect 195-96 (1976).

104. See Section II.B. in Part III.

105. See, for example, the Soviet Draft Declaration, Art. V, in Fifth Working Group Report, supra note 12, Annex II; the Soviet Draft Convention, Fourth Working Group Report, supra note 4, Art. V and the Swedish-Canadian Draft Principles, supra note 18, Art. V.

106. See, e.g., Ruddy, "Broadcasting Satellites: An American Perspective," 3 Lawyer of the Americas 499, 503 (1971). Among the relevant instruments are the First Amendment to the Constitution of the United States; the Universal Declaration of Human Rights, G.A. Resol. 217A (III), 10 December 1948; The International Convention on the Elimination of All Forms of Racial Discrimination (articles 4 and 5) adopted by U.N. General Assembly Res. 2106A (XX) of 21 December 1965, and entering into force on 9 January 1969; The International Covenant of Civil and Political Rights (Article 19), adopted by U.N. General Assembly Res. 2200 (XXI), 16 December 1966; The European Convention of Human Rights (Article 10), signed at Rome, 9 November 1950, entered into force 3 September 1953; The American Declaration of the Rights and Duties of Man (Article IV), Res. XXX adopted at the Ninth International Conference of American States, Bogota, Colombia, 30 March to 2 May 1948; and The American Convention on Human Rights (Article 13), signed on 22 November 1969, at the Inter-American Specialized Conference on Human Rights, San Jose, Costa Rica.

107. U.N. General Assembly, The International Covenant of Civil and Political Rights, supra note 106, Art. 20. For similar limitations on the principle of free flow in other international instruments, see T. Buergenthal, "The Right to Receive Information Across National Boundaries," in Aspen Institute Program on Communication and Society, Control of the Direct Broadcast Satellite: Values in Conflict 76-68 (1974).

108. Laskin, "Legal Strategies for Advancing Information Flow," Aspen Institute, Control of the Direct Broadcast Satellite, supra note 107, at 62.

109. L. Marks, "International Conflict and the Free Flow of Information," in Aspen Institute, Control of the Direct Broadcast Satellite, supra note 107, at 69.

110. Ruddy, supra note 106, at 503-504.

111. Accord, Laskin, "Legal Strategies," supra note 108, at 61.

112. Id.

113. Id.

114. See, e.g., the Soviet Draft Declaration, Arts. IV and V, in Fifth Working Group Report, supra note 12; Soviet Draft Convention, Arts. IV, V and VI, supra note 4.

115. Swedish-Canadian Draft Principles, supra note 18, Art. V.

116. ASIL Panel, Direct Broadcasting from Satellites, supra note 2, at 30.

117. Id.

118. Proposals for the exclusion of spillover from the prior consent regime are discussed below in the text accompanying notes 127-133.

119. UNESCO Declaration of Guiding Principles in the Use of Satellite Broadcasting for the Free Flow of Information, the Spread of Education and Greater Cultural Exchange, U.N. Doc. A/AC.105/109 (1972), Art. V(1). For further information see D. Smith, Communications Via Satellite: A Vision in Retrospect 199-200 (1976).

120. UNESCO, Declaration of Guiding Principles, supra note 167, Art. V(2).

121. Id., Art. VI(2).

122. Id., Art. VII(2).

123. On the doctrine of "harmful effects," see D. Smith, International Telecommunication Control 185-205 (1969).

124. UNESCO, Declaration of Guiding Principles, supra note 167, Art. IX(2).

125. Laskin and Chayes, "A Report of the Panel on International Telecommunications Policy," in ASIL Panel, Direct Broadcasting from Satellites, supra note 2, at 9.

126. See also Laskin, "Legal Strategies," in the Aspen Institute, Control of Direct Broadcasting Satellites, supra note 108, at 62.

127. Chayes and Chazen, "Policy Problems," supra note 102, at 15.

128. Comment of Abram Chayes in Panel Discussion, "Direct Satellite Broadcasting," supra note 100, at 78.

129 Note, "Approaches to Controlling Propaganda and Spillover from Direct Broadcast Satellites," 5 Stanford Journal of International Studies 175 (1970).

130. Id.

131. The text of § 428A is reprinted in the text accompanying note 41.

132. _Fourth Working Group Report_, _supra_ note 4, Annex IV, Art. VI; _Fifth Working Group Report_, _supra_ note 12, Annex III, Art. VI.

133. _Id._, Art. VIII.

134. U.N., UNESCO, _Declaration of Guiding Principles_, _supra_ note 119, Art. VI(2).

135. _Fifth Working Group Report_, _supra_ note 12, Annex III, Art. V.

136. Dalfen, "Direct Satellite Broadcasting," 20 _University of Toronto Law Journal_ 366, 373 (1970).

137. U.N., UNESCO, _Declaration of Guiding Principles_, _supra_ note 119, Art. VI(2).

138. Swedish-Canadian Draft Principles, _Fifth Working Group Report_, _supra_ note 12, Annex III, Art. V.

139. See, for example, Dalfen, "Direct Broadcasting," _supra_ note 136, at 373; E. McAnany, "Reflections on the International Flow of Information," in The Aspen Institute, _Control of the Direct Broadcast Satellite: Values in Conflict_ 16 (1974).

140. _See_ Ruddy, "Broadcasting Satellites," _supra_ note 106, at 503.

141. Comment, "Direct Broadcast Satellites: Implications for Less Developed Countries," 12 _Virginia Journal of International Law_ 84 (1971).

142. United States Draft Principles, _Fifth Working Group Report_, _supra_ note 12, Annex IV, Art. V.

143. _See_ also Marks, _supra_ note 109, at 66.

II. IMPLICATIONS OF THE CPUOS DEBATES ON EARTH RESOURCES SATELLITES FOR SPACE INDUSTRIALIZATION

1. See, e.g., Report of the Working Group on Remote Sensing of the Earth by Satellites on the Work of its Third Session, U.N. Doc. A/AC.105/125 (1973).

2. Report of the Legal Sub-Committee on the Work of its Twelfth Session, U.N. Doc. A/AC.105/115 (1973), at 14 [hereinafter cited as Twelfth Legal Sub-Committee Report].

3. U.N. Doc. A/C.1/1047, October 15, 1974 [hereinafter cited as Argentina-Brazil Draft Treaty]. The joint proposal superceded both Argentina's Draft International Agreement on Activities Carried Out Through Remote Sensing Satellites Surveys of Earth Resources, U.N. Doc. A/AC.105/C.2/L.73 and Brazil's Draft Treaty on Remote Sensing of Natural Resources by Satellite, U.N. Doc. A/AC.105/122. Both individual proposals are reprinted in the Report of the Legal Sub-Committee on the Work of its Thirteenth Session, U.N. Doc. A/AC.105/133 (1974), Annex IV, at 1-3 and 3-5, respectively [hereinafter cited as Thirteenth Legal Sub-Committee Report].

4. Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, 610 U.N.T.S. 205, 18 U.S.T. 2410, T.I.A.S. No. 6347, *entered into force* October 10, 1967.

5. U.N. Doc. A/AC.105/C.2/L.99, May 27, 1974 [hereinafter cited as Soviet-French Draft Principles]. The joint document superceded both the Draft Principles Governing Remote Sensing of Earth Resources from Outer Space submitted by France, U.N. Doc. A/AC.105/L.69, and the Model Draft Principles Governing the Use of Space Technology by States for the Study of Earth Resources, submitted by the Soviet Union, U.N. Doc. A/AC.105/C.2/L.88. All three are reprinted in Thirteenth Legal Sub-Committee Report supra note 3, at Annex IV, at 9-10, 5-8, and 9, respectively.

6. Id., Article 2.

7. Id., Article 5(b).

8. Id., Article 5(c).

13. Argentine Draft Treaty, _supra_ note 12, at 30; Cocca, _supra_ note 30, at 175.

14. Cocca, _supra_ note 30, at 175.

15. Union of Soviet Socialist Republics: working paper "Draft Treaty Relating to the Moon -- Question of the "Common Heritage of All Mankind" U.N. Doc. A/AC.105/115 (1973), Annex I, at 24-25.

16. E. Vassilevskaya, "Drawing Up a Draft Treaty on The Moon -- a Further Contribution to the Progressive Development of International Space Law," in _Proceedings of the Nineteenth Colloquium on the Law of Outer Space_ 101 (1977).

17. _See_, _e.g._, Gorove, _supra_ note 11, at 179.

18. _Id_, at 177-78.

19. Stephen Gorove, The Draft Treaty Relating to the Moon: An Overview and Evaluation," in _Proceedings of the Nineteenth Colloquium on the Law of Outer Space_ 44 (1977).

20. _See_, _e.g._, Dr. Laszlo Szaloky, The Way of the Further Perfection of the Legal Regulation Concerning the Moon and Other Celestial Bodies, Especially Regarding the Exploration of Natural Resources of the Moon and Other Celestial Bodies, in _Proceedings of the Sixteenth Colloquium on the Law of Outer Space_ 198 (1974); and Vladimir Kopal, The Development of Legal Arrangements for the Peaceful Uses of the Moon, in _Proceedings of the Fifthteenth Colloquium on the Law of Outer Space_ 163 (1973).

21. _See_, _e.g._, Cocca, _supra_ note 12, at 172-76; R. V. Dekanozov, "Relationship Between the Status of Outer Space and the Statuses of Areas Withdrawn from State Sovereignty", E.G. Vassilevskaya, "Introductory Report to Part IV", and Vladimir Kipal, "Legal Questions Relating to the Draft Treaty Concerning the Moon", _Proceedings of the Sixteenth Colloquium on the Law of Outer Space_ (1973), at 10, 170 and 183-4, respectively.

22. Vassilevskaya, _supra_ note 16 at 100-101; Proceedings of the United Nations Committee on the Peaceful Uses of Outer Apace, 19th Session, U.N. Doc. A/AC.105/PV 164 (1976), Statement by Delegate Cocca from Argentina and Proceedings of the United Nations Committee on the Peaceful Uses of Outer Space, 18th Session, U.N. Document A/AC.105/PV 146 at 58-60, Statement by Ambassador Bennett of the United States.

23. Proceedings of the United Nations Committee on the Peaceful Uses of Outer Space, 19th Session, U.N. Doc. A/AC.105/PV 164, Statement by delegate Macaulay from Nigeria.

24. Proceedings of the United Nations Committee on the Peaceful Uses of Outer Space, 18th Session, U.N. Doc. A/AC.105/PV 147 (1975), at 72-73, statement by delegate Bassols from Mexico; and Proceedings of the United Nations Committee on the Peaceful Uses of Outer Space, 19th Session, U.N. Doc. A/AC.105/PV160 (1976), statement by delegate Salatun from Indonesia.

25. Proceedings of the United Nations Committee on the Peaceful Uses of Outer Space, 18th Session, U.N. Doc. A/AC.105/ PV 149 (1976), at 59-60, statement by delegate de Lims from Brazil.

26. Edward R. Finch, and Amanda Lee Moore, Outer Space Law and the Global Community, 8 The International Lawyers, October 760-761 (1974).

27. Gorove, supra note 19, at 43.

28. Vladimir Kopal, Legal Questions Relating to the Draft Treaty Concerning the Moon; in Proceedings of the Sixthteenth Colloquium of the Law of Outer Space 181 (1974); E. Vassilevskaya, Legal Problems of the Exploration of the Moon and Other Planets, in Proceedings of the Sixteenth Colloquium on the Law of Outer Space 168-169 (1974); G.C.M. Reijonen, The History of the Draft Treaty on the Moon, in Proceedings of the Nineteenth Colloquium on the Law of Outer Space 361 (1977).

29. Vassilevskaya, supra note 28, at 169-70.

30. India: working paper, Draft Treaty Relating to the Moon, U.N. Doc. A/AC.105/115 (1973), Annex I, at 22.

31. Bulgaria: working paper, Draft Treaty Relating to the Moon, U.N. Doc. A/AC.105/133 (1974), Annex I, at 6.

9. *Id.*, Article 5(a).

10. *Id.*, Article 6.

11. U.N. Doc. A/AC.105/C.2/L.103 (19 February 1975) preambular paragraphs 3 and 4.

12. *See* Report of the Legal Sub-Committee on the Work of its Fourteenth Session, U.N. Doc. A/AC.105/197 (1975), Annex III, at 2 [hereinafter cited as *Fourteenth Legal Sub-Committee Report*].

13. Report of the Legal Sub-Committee on the Work of its Fifteenth Session, U.N. Doc. A/AC.105/171, Annex III, at 2 - 3 [hereinafter cited as *Fifteenth Legal Sub-Committee Report*].

14. *See* the analysis of Article I in Section I.A. of Part II above.

15. *See, e.g.*, the working paper on remote sensing submitted to CPUOS by the United States delegation entitled "Remote sensing of the *natural environment* of the earth from outer space," U.N. Doc. A/AC.105/L.103, 19 February 1975 (emphasis added).

16. *See, e.g.*, Declarations of Principles Governing the Sea-Bed and the Ocean Floor, and the Subsoil Thereof, beyond the Limits of National Jurisdiction, G.A. Res. 2749, 25 U.N. GAOR Supp. 28, at 24, U.N. Doc. A/8028 (1970).

17. *See* Fifteenth Legal Sub-Committee Report, *supra* note 13, Annex I, at 2 - 3. For a discussion of the moon treaty, *see* Section III below.

18. For a more extensive discussion of the common heritage principle, *see* Section IV of Part III, below.

19. *Fourteenth Legal Sub-Committee Report*, *supra* note 12, Annex III, at 2.

20. *See, e.g.*, G.A. Res. 2151 (XXV) (1970).

21. U.N. Doc. A/AC.105/C.2/L.107 (1976), reprinted in _Fifteenth Legal Sub-Committee Report_, _supra_ note 13, Annex IV.

22. _Id._, Annex III, at 2-3.

23. _Fifteenth Legal Sub-Committee Report_, _supra_ note 13, Annex III, at 2, note C.

24. _Fourteenth Legal Sub-Committee Report_, _supra_ note 12, Annex III, at 2.

25. The term "co-operation" appears again in Article III, in which states are required to conduct space operations in accordance with international law in order, _inter alia_, to promote general international co-operation and understanding, and in Article IX which provides for consultation between states if the space activities of one state appear to jeopardize the interests of another. However, consultation is not directly connected to the concept of co-operation.

26. United States Working Paper, U.N. Doc. A/AC.105/C.2/L.103 (February 19, 1975), reprinted in Report of the Legal Sub-Committee of the Work of its Thirteenth Session, U.N. Doc. A/AC.105/133 (June 6, 1974), Annex IV, article IV.

27. _Fifteenth Legal Sub-Committee Report_, _supra_ note 13, Annex III, at 3.

28. _Id._

29. _Fifteenth Legal Sub-Committee Report_, _supra_ note 13, Annex III, para 8.

30. The common elements from the 1976 session are set forth in _Fifteenth Legal Sub-Committee Report_, _supra_ note 13, Annex III, at 3.

31. _Id._

32. _Id._ Compare with _Draft Principles Governing Activities by States in the Field of Remote Sensing of Earth Resources by Means of Space Technology_, U.N. Doc. A/AC.105/C.2/C.99 (1974), reprinted in _Report of the Legal Sub-Committee on the Work of its Thirteenth Session_, U.N. Doc. A/AC.105/133 (1974), Annex IV [hereinafter cited as _Thirteenth Legal Sub-Committee Report_].

33. _Fifteenth Legal Sub-Committee Report_, _supra_ note 13, Annex III, at 3.

34. _See_ Section I.A. in Part II above.

35. See Section I.A.1. in Part II above.

36. A similar provision is continued in Article XIII of the Argentine-Brazilian Draft Treaty, U.N. Doc. A/C.1/1047 (1974), reprinted in Thirteenth Legal Sub-Committee Report, supra note 32, Annex IV.

37. See S. 657, 95th Cong., 1st Sess. (1977).

38. See Hearings on S. 3374 Before the Senate Committee on Aeronautical and Space Sciences, 91st Cong., 2d sess. (1970), part III, at 1063-64.

39. Report of the Working Group on Remote Sensing of the Earth by Satellites in the Work of its Third Session, U.N. Doc. A/AC.105/125, March 13, 1974, at 12.

III. IMPLICATIONS FOR SPACE INDUSTRIALIZATION OF THE CPUOS DEBATES ON THE DRAFT MOON TREATY

1. Argentina, Draft Agreement on Principles Governing Activities in the Use of the Natural Resources on the Moon and Other Celestial Bodies, U.N. Doc. A/AC.105/C.2/C.71 (1970).

2. U.S.S.R., Draft International Treaty Concerning the Moon, A/8391 (1971).

3. G.A. Res. 2779 (XXVI) (1971).

4. See Report of the Legal Sub-Committee on the Work of its Eleventh Session, U.N. Doc. A/AC.105/101 (1972).

5. Report of the Chairman of Working Group I (Moon Treaty), in Report of the Legal Sub-Committee on the Work of Its Fourteenth Session, A/AC.105/147 (11 March 1975), Annex I, at 1 (hereinafter cited as Fourteenth Legal Sub-Committee Report).

6. Stephen Gorove, Property Right in Outer Space: Focus on the Proposed Moon Treaty; 2 Journal of Space Law 27, 30 (1974); L.F.E. Goldie, "Is There A General International Law of Original Ownership? The Possible Relevance of General Doctrines Governing the Possession of Deep Ocean-Bed Resources, in Proceedings of the Nineteenth Colloquium on the Law of Outer Space 288-289 (1977).

7. Goldie, supra note 6, at 288-289.

8. Id.

9. See, e.g., E. Vassilevskaya, Legal Regulation of Activities on the Moon for the Cause of Peace and Progress, Proceedings of the Fifteenth Colloquium on the Law of Outer Space 180 (1973).

10. Gorove, supra note 6, at 30.

11. Gorove, Legal Status of the Natural Resources of the Moon and Other Celestial Bodies, Proceedings of the Sixteenth Colloquium on the Law of Outer Space 179 (1974).

12. See Argentina, "Draft Treaty Relating to the Moon - Question of the 'Common Heritage of All Mankind'," U.N. Doc. A/AC.105/115 (1973) Annex I, at 29; see also A. Cocca, The Principle of the "Common Heritage of All Mankind" As Applied to Natural Resources from Outer Space and Celestial Bodies, in Proceedings of the Sixteenth Colloquium on the Law of Outer Space 173 (1974).

E. SPACE INDUSTRIALIZATION EDUCATION

APPENDIX E:

SPACE INDUSTRIALIZATION EDUCATION

(A paper by K. M. Joels written for
Rockwell International Space Division

Page

INTRODUCTION

From the court school of Charlemagne in the beginning of the ninth century through the founding of the universities and schools of Europe, education has consisted basically of both the impartation of culture and knowledge and career training. The printed word and the teacher were the major learning media and the student was required to be in attendance at the school in order to participate in school functions. The modern school system reflects the institutionalization of the western educational tradition, and is now being acted upon by new forces which may require great change to allow the school to fulfill both its traditional purpose and the new duties that have been relegated to the educational community.

New media, examples being televised instruction, video and audio cassettes, computer managed and assisted instruction (CMI and CAI), radio broadcasting, film and slide media, have been incorporated with varying degrees of success in the school context. Distribution and implementation of these media has been limited by the factors of cost, applicability, and availability. Satellite technology has introduced a synoptic distribution system for various transmittable educational media. Early educational satellite experiments have shown certain strengths and weaknesses of this approach.

To the present, the cost of communications satellite distribution for educational programming has been high. There emerges from the literature a paradigm which applies equally to other educational applications. This is, that all media are effective within certain applications and under certain constraints. It remains for us to identify the areas of applicability of communication satellite technology and to apply present or improved technology within the identified constraints.

The extra-terrestrial imperative is an optimistic possibility for human advancement. It is based on the concept of intelligent growth, the need and availability of space to meet terrestrial problems, and the global psychology of concentrated human effort. Rene Dubos notes that mankind may be developing into a super-organism. Man's cumulative planetary consciousness based on evolution and survival needs may overcome the geographical limitations which exist on earth. Enlarging human options requires education to make these options understandable, participatory, and operational.

The individual human organism primarily seeks survival and security and perceives education as the vehicle for providing the necessary mental and physical prowess. But humans are only willing to sacrifice so much for the privilege of education as has been noted in the inability to pass school bond issues, or the slowness with which many groups and nations establish effective educational systems. The desire seems to be there but the means is often lacking.

Let us look then at the components of an educational system based on, and perhaps enhanced by, space industrialization communications technology.

We will first look at the state of the art today in satellite communication and educational media and its limitations. Then, outlining some basic theoretical specifications for an educational satellite telecommunications system, we will examine some domestic and international mini-scenarios and rational for utilization of such a system. Finally, areas for goods and services marketed as a result of such a system, and jobs that the existence of such a system might provide are listed.

Putting numbers to any system will require further development of cost estimates and capabilities of proposed space industrialization communication systems, but this synthesis is intended to spark further such development.

1.0 Existing Systems for Communication Satellite Education.

Since the first technical papers on communication satellites by Eric Burgess and Arthur C. Clarke in the late 1940's, the idea of an orbiting transmission link has been perceived as a less expensive mode of communication. Our historical experience in the development of communication satellites has been evolutionary, and not quantum in nature. Each technological jump is really a logical evolutionary step in the development of communications systems. From the Echo balloon to Telstar to ATS-1, -3, -6, and finally CTS, we see improvements in satellite capacity, signal quality, and a reduction in cost of ground facilities. The Intelsat and Westar systems show increasing reliability for voice, television, and data transmission and decreasing cost for user time in the commercial setting.

1.1 Satellite Systems.

1.1.1 ATS-6.

The ATS Series was designed to provide synoptic communications coverage to widely dispersed areas. Reception of signals rebroadcast from the ATS-6 satellite were to be accomplished with low cost receivers. ATS-6 video transmission achieved a cost of $1000.00 per hour. Experiments involving the ATS satellite included: wide distribution of materials to geographically inaccessible areas of the United States, for example, Appalachia, the Western Rocky Mountain Region, Alaska; and experiments in India, et al., for the dissemination of educational and informational programming to remote villages which were, except for the ATS antenna, electronically isolated from the outside world. At this writing, results of the India experiment are still being compiled but published reports on the domestic experiments indicate a high degree of satisfaction with the technical aspect of the experiment, but due to costs

1.1.1 --Continued.

and the limited nature of applications thus far, a reserved optimism exists about future satellite utilization.

1.1.2 CTS.

A joint Canadian-American spacecraft, the CTS enhances the spacecraft's retransmission capability to service smaller ground receiving stations. Additionally, CTS is being used on a regular basis for two-way interchange of information and testing video compression techniques which would reduce the amount of satellite time involved in sending a given amount of television information. The television signal is encoded, compressed, transmitted, and then expanded to its original length. This results in increased satellite relay capacity and reduces the overall cost of transmission by reducing impact on the satellite transponder.

1.1.3 WESTAR.

The Western Union System has launched the Westar satellite with commercially available television transponders, message switching capability, and audio transmission capability. The cost per television transponder per annum ranges from 1.2 to 2.7 million dollars. While this seems to be a prohibitive initial cost to non-commercial applications, it shoul[illegible] pointed out that this breaks down to approximately $25[illegible].00 per hour without any video compression techniques. This reduces ATS transmission costs by a factor of four. It is also interesting to note that Westar as a commercial system must be amortized on a profit basis.

1.1.4 Public Service Satellite Concepts.

Recent activities and workshops at the Goddard Space Flight Center (October and December 1976) are tending toward the development of Public Service satellite utilization. The

1.1.4 --Continued.

concept stems from analysis by teams of highly qualified communicators, educators, and engineers regarding public usage of satellite facilities. The efforts are seen as an adjunct to "public broadcasting", and to fulfill the needs of non-profit users in our society who would presumably not be able to participate at commercial rates. While this approach is logical, based on existing technology, quantum jumps in technology may make a system of this kind trivial. Technology tends to replace large public systems with even larger and more prolific private systems. Leading examples of this include telephone versus telegraph communications, and the personal automobile versus mass transit. A Public Service Satellite organization may evolve into a regulatory agency for user planning rather than a source for low cost satellite time.

1.2 Educational Media Communications Techniques.

Extensive research has been carried out over the past few decades on the effectiveness and appropriateness of educational media in the teaching process. The following list (from Educational Technology, The Design and Implementation of Learning System, CERI, Leiden, Netherlands, April 1970) depicts the basic media techniques found to have reasonable educational effectiveness:

- Print in all forms
- Moving visual and AV media (film, TV, videotape)
- Static visual media (slides, photos)
- Sound media (tape, radio, records)
- Situational information (role-playing, drama, case studies)
- Information from physical objects (models, simulators)
- Computers (CAI, CMI)
- Human resources (teachers and peers)

1.2 --Continued.

It should be noted that one medium does not necessarily account for a higher measured learning that any other media, but the applicability of different media to different situations would be the deciding factor in application.

1.2.1 Television.

The two primary strengths of the television medium are 1) distribution over a wide area and 2) the ability to transmit visual information as well as audio. The television medium can be used as a resource sharing mode for education because it can replicate an individual in an infinite number of places at a given time. Television learning generally requires more motivation due to a lack of ready feedback in the present system. N.B., the Stanford Educational Television Network, and CTS experiments between Carlton College in Canada and Stanford University in California, have utilized two-way audio to allow student feedback to a professor in a remote location. Given the generally high order of motivation of students participating in these programs, they have been reasonably successful. It should also be pointed out that a television can function as a CRT data processing terminal and can therefore be dual function in educational applications. Television has also been shown to be a successful educational medium for summarization and condensation, for example, dramatized condensations of literary and historic occurrences, summaries of lectures and programs, and the capability of multiple repetition by video tape rebroadcast. Television transcends both space and time as a learning tool. The classroom experience in time is unidimensional while television provides multidimensional options and frequent repetition.

1.2.2 Radio.

Long perceived as the ugly stepsister of television by the educational community, radio has some distinct economic advantages. The bandwidth necessary for radio transmission and the power requirements both being significantly less, radio is cheaper to transmit and to receive. A radio receiver operating in the megahertz range can be purchased for under ten dollars while the lowest cost black and white television receiver still remains around seventy-five dollars. The audio medium is effective in factual information dissemination, and for those applications where visual communication is not necessary, for example, non-illustrated lectures, news and calendar events, and review sessions. In addition, radio information is easy to store on simple home recording cassette equipment and radio production costs are significantly lower than those for television (approximately $5000.00 per hour for educational television versus approximately $1000.00 per hour for educational radio).

1.2.3 Two-way Transmission.

Two-way transmission (video-video, video-audio, or audio-audio) is a technique used only peripherally in today's curriculum. This is largely due to the technical difficulties in arranging compatible equipment and the cost of transmission. The simplest transmission techniques (telelectures, etc.) involve audio input to a classroom with a feedback capability over a commercial telephone hook-up. Costs tend to be fairly high because there is a limit to the number of people who can be adequately served in a two-way situation and a minimum cost on the utilization of the telephone system. Video-audio links and video-video links are prohibitively expensive and complex and have only been used in more experimental situations. Like the other educational media, two-way transmission has several distinct educational advantages. It provides interaction

1.2.3 --Continued.

between teacher and student; it provides an option for student-to-teacher feedback; and it provides real time guidance and evaluation by the teacher. While equipment complexity and costs remain high, two-way transmission cannot be seen as a significant educational tool, but rather as a "public service" device best suited to motivational and "special" usage. Results of various contemporary satellite test projects seem to bear out this conclusion (see Bibliography).

1.2.4 Data Processing.

As man increases his speed of travel or communication, he increases his capabilities unidimensionally by saving time, then when he couples this capability with large scale data storage and manipulation systems he is mutiplying his thinking power as well, and realizing greater benefits. The computer, as a resource in education, has been used as tutor, instructional manager, information dispenser, and labor saving slave. The increase in personal computational power over the past few years may be as significant for society as the increase in personal communication and transportation of recent decades. As man increases interaction with other men, his tools for mental extension must also interact. Stored information must be conveniently retrievable, and new information must be readily accessible. Transmission using data processing techniques provides an extremely rapid method of disemminating, compiling, and operating on information. Limiting cost factors include the cost of equipment and of "connect" time. These costs have been prohibitive for the individual or the educational user.

1.2.5 Peer Group Learning.

Sociometrically, peer groups are extremely influential learning stimulae. It has been argued that as much learning takes place from the peer group as from the institutionalized

1.2.5 --Continued.

educational system. Peer groups form around social, religious, economic, geographical, and intellectual lines and the increase in personal communication capability can increase the geographical impact of a given peer group. In addition, peer groups also provide paraprofessional educational input and a greater effort must be made to identify and direct this stimulus to the most productive end possible. For peer groups interacting solely via electronic communications, for example, commerical telephone, connect time between members of the peer group is mostly limited to a one-to-one basis and is moderately expensive.

1.3 Limitations of Present Systems.

The following is an itemized summary of limitations that must be overcome in order to provide extensive educational services using the previously described educational media via satellite systems.

1.3.1 Cost of Receiver.

Depending upon the mode of communication, a receiver could be a television set, a radio, or an alphanumeric readout device, such as CRT or hard-copy data terminal. Domestic and worldwide sales indicate that radio receivers are available to most areas of the world. Television receiver usage is restricted by power requirements and per unit cost, yet the number of television receiver units is rapidly proliferating on a global basis. The proliferation of data processing equipment is severly limited by both cost and availability and has not made a significant impact on education in most areas including areas of medium to high technology. Radio receivers and television receivers can be acquired for \$10.00 and \$100.00 respectively, but DP equipment is at least an additional order of magnitude in price.

1.3.2 Cost of Antenna.

Assuming the presence of a large scale broadcasting and satellite retransmitting facility, the second major user expenditure would be the cost of the antenna system. As the power used in transmitting goes up antenna requirements and costs can be reduced. When the antenna cost ceases to be a significant fraction of the receiver cost, it will be affordable by a majority of the user population (see Appendix).

1.3.3 Cost of Transmitter (Two-way).

Any two-way communication requires a transmitter, with radio transmitters significantly lower in cost than vide. transmitters. Technological trends suggest that the cost of a radio transmitter can be brought within the range of a mass market larger than that created for Citizens Band. Television transmitters, however, remain complex and therefore have a high unit cost.

1.3.4 Cost of Microphone/Camera (Two-way).

The microphone or camera is the two-way transmission input device. Microphones of sufficient quality for personal broadcast are readily and inexpensively attainable and would be a small fraction of a total receiver-antenna-transmitter package. Television cameras can be obtained (vidicon) in the range of $200.00 to $600.00 each. Solid-state cameras (CCD or other compatible technology) are anticipated to cost about $500.00 in a mass market situation.

1.3.5 Operational Ease.

The genious of both the automobile and the telephone is that an individual can learn to use the device with a minimum of effort and that it is a highly reliable instrument. Experiments with ATS-1 and -3 and the necessary equipment for ATS-6 and CTS suggest that an additional order of magnitude

1.3.5 --Continued.

would be necessary in ease of operation to allow convenient usage of satellite communication systems on a large scale. Receiver units (radio/television) are already extremely easy to use, but transmission devices are moderately complex and would require design simplification.

1.3.6 Coordination.

A prime weakness which the educational community has failed to overcome is the absence of overall coordination in the development and implementation of a coherent satellite utilization program. Different user groups with specific needs may have to combine or submit to an overall coordinating agency. This agency could be profit making in nature, or, less desirably, a part of government.

1.3.7 Maintenance.

Implementation of any large scale communications system requires correlative implementation of a maintenance program not unlike the maintenance programs established by manufacturers for lease or purchase products in the electronics industry. The absence of skilled maintenance people has been a limiting factor in enlarging satellite utilization from limited experiments to full scale operations. Each project has been individually well staffed and maintained, but the overall expertise does not exist to support a vast extension of such a program at this time.

1.3.8 Transmission Quality.

Many of the early experiments in education using communication satellites have suffered from broadcast transmission quality deficiencies. High quality is requisite for a satisfied public. As has been evidenced with commercial

1.3.8 --Continued.

broadcasting, when the quality drops below certain admissible levels, standards to which the user has grown accustomed, user participation and utilization may fall off sharply.

1.3.9 Availability/Reliability.

The individual user of a satellite system must have a selection of programming and services available at a level of reliability at least equal to that of commercial broadcast services . Education, while a perceived need of the society, must also compete with commercial broadcast, and normal social activities for a user's time and must therefore be presented in a palpable and technically satisfying way.

1.3.9.1 Time Zone Differences.

In making programming available, it should be noted that geographic distributions may require the modification of delivery systems to account for time zone differences. This is mentioned because it was identified as a problem in some of the international experiments undertaken with the ATS series satellite to unite educators from widely dispersed areas.

2.0 Space Industrialization Communications Technology.

As outlined in a previous section, limitations to extensive utilization of present satellite technology for educational purposes create a somewhat discouraging picture. In fact, responsible political and social organizations are already engaged in the development of a "public service" scheme for educational satellites. While this concept may be necessary for the introduction of satellite technology to the people of this country and other countries, it relegates this type of satellite usage to the "non-profit" domain and discourages the business community (with the exception of companies engaged in the sale of educational materials) from participation. There is, however, in Kraft Ehricke's expostulation of the Extra-terrestrial Imperative, an option which may obviate this "stepchild" approach to educational satellite telecommunications. That option is to utilize Space Shuttle related technology and Large Space Structures (LSS) to construct a system with a quantum advancement in communication capability and a quantum reduction in user cost. The "push" provided by our present educational research and our need to increase educational productivity coupled with the "pull" of a satellite user cost breakthrough, may make educational and related activities one of the prime movers for future satellite system development.

2.1 Basic Assumptions.

2.1.1 Shuttle Technology/LSS.

Any space industrialization endeavor requires the use of reusable launch vehicles The size of Large Space Structures (LSS) is dependent upon cost factors related directly to payload orbital costs.

2.1.2 Throughput Costs.

Transmissions (either one-way or two-way) must be provided at nominal cost to insure maximum user utilization in the public sector.

2.1.3 Distribution Quality.

Distribution of broadcast material, whether by satellite direct to remote areas or by satellite to urban networks of cable or fiber optics, must be accomplished with a quality approximating commercial broadcast levels.

2.1.4 Capacity.

Availability of programming and interactive channels must be of such an order of magnitude as to provide extensive choice and easy access. This condition is parallel to the availability of the telephone, which can handle the majority of calls without major tie-ups. A limited capacity system, which now exists, frustrates both producers and users of materials for education.

2.2 Theoretical Specifications for LSS Educational Satellite Utilization.

User costs will be the prime factor in the success of any system, assuming the benefits of such a system are clearly perceived by the public.

2.2.1 System Availability.

The space industrialization communications scenario will assume that there are n-channels of audio available to the user for one-way or two-way communication, n-channels of video, and n-channels for data processing. The n-channels carry program distribution as well as individual interaction.

2.2.2 Antenna Costs.

This scenario assumes an audio and video antenna cost for standard receivers of less than $25.00 per antenna, that is, per household.

2.2.3 Video Transmitter/Camera.

This study will assume the cost of a video transmitter and camera system capable of sufficient quality for two-way video interaction of less than $600.00 per unit. Note that this does not include any video storage capacity (video tape or video disc). While this is expensive, it at least reduces the cost of "getting in" to two-way video to the level of a major appliance purchase.

2.2.4 Audio Transmitter/Microphone.

This study will assume an audio transmission capability for direct system access at a cost less than $25.00 per transmitter/microphone unit. Studies done for NASA indicate that this may be a fairly readily obtainable goal.

2.2.5 On-line Costs (Connect time).

One-way or two-way interaction for either dissemination or interaction for educational purposes will carry the following cost estimates:

Data Processing (2-way) connect time...$1.00 per hour

Audio communication (2-way)............$1.00 per hour

Video communication (2-way)............$2.50 per hour

N.B. These costs could be achieved only with large user populations and an extremely advanced satellite system. Present computer network connect times can be as low as $4.50 per hour, for example, Telenet. Audio, now available primarily through commercial telephone, can be as low as $11.00 per hour coast

2.2.5 --Continued.

to coast, and essentially free within local dialing areas. Video transmission based on Westar technology could be available at about $250.00 per hour and would require a reduction of two orders of magnitude to scenario criteria.

2.3 Space Industrialization Educational Communications System.

The components of the system envisioned in this scenario based on LSS technology are outlined as follows:

2.3.1 Satellite System.

In a study for the National Aeronautics and Space Administration, Aerospace Corporation has outlined basic parameters for large communication satellites and their ability to interact with low-cost ground terminals. This scenario assumes the existence of such structures exhibiting the capabilities suggested in the Aerospace Corporation study.

1) Four LSS communications satellites would offer complete coverage of the continental United States,
2) Each LSS would have a dimension of about four miles square.

2.3.2 G ound Support Systems.

This study will assume the existence of ground broadcast facilities for both programming distribution and individual user interaction at cost levels defined in Sections 2.2.3, 2.2.4, and 2.2.5.

2.3.3 Coding.

A major element of either a domestic or international educational satellite system is the capability of "selective" access to materials and individuals. Therefore, there would be a need for transmission coding systems. Such an encoding/decoding capability would anticipate and overcome the following limitations:

2.3.3.1 Political Integrity.

In an international setting, unlimited personal intercommunication could be threatening to the political community and thereby eliminate the possibility of installing an LSS communications system. Domestic and international programming and communication when coded offers control from misuse.

2.3.3.2 Privacy.

Individual users would need to be assured of privacy for their personal communication. Coding capabilities could provide the necessary privacy acting as "scrambler".

2.3.3.3 User Analysis.

Coding would also permit analysis of user utilization, evaluating load factors, and permitting convenient documentation for billing. Coding provides an automatic stratification of users for a broadcasting entity. The broadcaster can market "decoders" for specific programs similar in concept but not in hardware to the cable television subscription service offered today.

2.3.3.4 User Access.

Coding provides for stratified user access within an educational system by allowing control of personal interaction

2.3.3.4 --Continued.

and access to desired programming. Coding systems may allow multiplexing which provides the user with a variety of communications media and channels at the same time. For example, the user may be receiving a video program while asking questions of a peer by overwriting the program with alphanumerics on the peer's video screen.

2.3.3.5 Possible Coding Techniques.

In an educational satellite distribution system coding may be provided by internal electronic circuitry, such as scrambler circuits with magnetic cards activating (keying) access to certain programming with frequency allocation controls to limit certain bands to certain uses; or with controlled equipment compatability, for example, varying video rastors, baud rates, etc.

3.0 Areas of Impact (Domestic).

Assuming the existence of the system described in Section 2.0, the following mini-scenarios describe potential user situations in the area of education.

3.1 The School Setting.

Projected trends in the United States show a school population which is getting progressively older. Demographics suggest a population increase in the 1990's, but the next decade will be spent serving a decreasing formal school enrollment, and a substantially increasing adult student enrollment.

3.1.1 Elementary and Secondary Activities.

Traditional teaching involves small groups (10-30 students) in specific locations at specific times. Additional responsibilities, such as sex education, hygiene, etc., have been placed on the schools without regard for already strong peer group and family pressures in these areas. Efforts to involve parents in the educational process is minimal because it requires interaction outside the normal course of school activity. A space industrialization communications system offers interesting possibilities for bringing the school to the home and vice versa. N.B. No system will be effective if the teachers or their union representatives perceive classroom communication devices as an invasion of a teachers privacy, or an excessive burden on the teachers right to controlled and equitable in-service evaluation.

3.1.1.1 Scenario.

A television camera/transmitter with audio channel could be placed in the classroom and operated remotely and discretely by the teacher only. This one-way transmission can extend the classroom beyond its four walls.

3.1.1.2 Parent Visitation.

Parents can participate in school activities at predetermined times from their home or office setting and observe the class, their child's progress, or specific learning or diciplinary problems. The teacher can issue code keys for classroom "visitation" at remote locations. An erasable magnetic strip, not unlike those used for admission to modern rapid transit systems, could allow a single limited remote "visit". A general ticket could be provided for scheduled visiting days. This would not interrupt the normal flow of classes and provides greater opportunities for parent participation. Visiting days, or model classes could also be taped for rebroadcast at a more convenient time.

3.1.1.3 Sick Days.

Children who would normally miss school activities due to illness or even absence can, from the home or other remote location, participate through either one-way or two-way communication. Teachers can also "visit" absent pupils without travel to provide encouragement, give assignments, and answer questions.

3.1.1.4 Remedial Studies.

After school hour broadcasts, offered on a demand basis, could provide remedial or review sessions. This is parallel to the professors "review" session on the night before important examinations at the university level. This would be especially applicable at the junior high and high school levels, but could, involving students and paraprofessionals, become a regular feature of the school day.

3.1.2 Scenario.

A dozen or more video channels are available in the home with background educational programming during off-school hours.

3.1.2.1 Remote Schooling.

Children in families whose occupations require travel could, by following specific programming sequences, achieve school equivalency by testing. Not necessarily designed to replace the formal educational setting and the learning motivation it provides, remote schooling could stimulate additional learning outside the classroom, review for the slower student, stimulate the gifted child, teach the uneducated adults, and compensate for special social situations where formal education is difficult.

3.1.3 Resource Sharing.

As school budgets decrease due to inflation, decreased enrollments, and erosion of community support, it will be possible to share resources between districts using educational satellite capabilities. Video and data processing links individualize instructional capability by allowing students to tie into the classroom or programming sequence most appropriate to their level and rate of achievement. This type of program could be shared by open scheduled schools, or schools with modular or traditional scheduling. The individual school would, using this type of system, increase its ourse offerings and increase the "tracks" or levels of courses for different student learning rates.

3.1.3.1 Scenario.

A teacher skilled in remedial reading conducts a district wide series of special classes, while a science teacher conducts a special seminar for elementary students on space exploration. The children participate during "open period" scheduled for each school at pre-arranged times.

3.1.3.2 Scenario.

Three high schools can participate in a talk given by an international sports figure and ask questions via two-way audio link.

3.1.3.3 Scenario.

Administrators and United Federation of Teachers representatives hold a special session informing teachers of their new privileges and obligations under the new contract, with teacher audio input from the lounges in the district's schools.

3.1.4 Data Transmission-Library Services.

Traditionally limited elementary and secondary school libraries can benefit by regional, district, or community interaction. These resources can be accessed or supplemented electronically using local or regional data bases.

3.1.4.2 CMI and CAI.

Computer Managed Instruction and Computer Assisted Instruction can be made available for a large number of users over a wide area via satellite link. The primary cost for these services lies in the availability of computer time and the cost of that time and the necessary access hardware.

3.1.4.3 Scenario.

Low cost typewriter terminals and intelligent terminals using data cassettes could be purchased at prices approaching today's electric typewriter and audio cassette recorder when applied to a mass market. Low "connect time" charges via educational satellite network could provide an immense market for CMI and CAI program utilization. Programs could be batch transmitted to the intelligent terminal for later use or operated on-line if sufficient user capability exists.

3.1.4.4 Scenario.

Educational software marketing firms utilizing network accounting procedures and evaluation monitoring programs can measure utilization of programs, levels of success, and evaluation of specific program components for continual update and improvement. Programmed courses are available for basic elementary and secondary skills, career preparation, language study, etc., supplementing the school curriculum.

3.2 The Home Setting.

As formal education spills over into the home, many home educational activities can be generated or enhanced through satellite communications technology.

3.2.1 Individual Interests.

Hobbies and career training are two areas of education that have experienced explosive growth in the last few years. The job market forces a change of careers several times during a worker's productive lifetime. Hobbies (pottery, jewelry-making, etc.) have become not only creative pastimes but also sources of supplemental income.

3.2.1.1 Scenario.

Courses presently offered by community adult education programs and junior colleges can be distributed to large numbers of home users at convenient times without requiring a visit to a campus. With the exception of laboratory experiences (some of which may still be accomplished in the home), factual information, guidance for home or small business endeavors, and tutoring can all be distributed via educational satellite system. The delivery cost of such programming and services decreases with the total number of users, and depending on that number, make the services reasonable enough for a majority of the population of adult learners to participate. Many

3.2.1.1 --Continued.

learners who could be self-conscious or feel inferior could also participate from the privacy of the home setting.

3.2.2 Peer Group Interaction.

As outlined in previous sections peer group interaction is both an important part of the social process and the educational process. Low cost, wide ranging communication capability could stimulate the development of peer group interaction over wider geographical areas and permit peer groups for even the most specialized tasks or interests. Historically, peer group development was spontaneous and based on specific interests and needs. Tedious formalism of hundreds of "national conventions" is an example of the institutionalizing of peer group interaction. Much more might be accomplished from such meetings, and many more peer groups might be formed if low cost, multi-channel communications capabilities existed. Perhaps multi-channel simultaneous communications could permit peer group interaction over continental and intercontinental distances.

3.2.2.1 Scenario.

Twelve computer hobbyists interested in home-built parallel processing computer systems but located in five states maintain monthly meetings and almost nightly interaction via two-way audio and CRT communication comparing software and passing along computer architectural advice.

3.2.3 Household Management.

Many fundamental societal problems stem from the inability of the individual to effectively manage his own affairs. Extensive educational utilization of communications could be extremely helpful for reaching the home with the type of data that would make people better managers. Parenting,

3.2.3 Household Management.

economic management, budget decorating, etc. can all lead to a better self-concept and enhanced capability for coping with the modern home environment. Delivery of such educational materials directly to the home at convenient times would be vital to the success of the program.

3.2.3.1 Scenario.

A course in coping with hyperactive children and monthly review sessions in balancing a checkbook could be broadcast, and questions could be answered by developing contacts with a local paraprofessional communications center or a peer group.

3.3 The Work Setting.

3.3.1 OJT and In-service Training.

On the job training and in-service training are two major tasks facing any corporation or institution. Extensive educational programming exists either in-house or externally generated to fulfill these needs. Unfortunately, much of this information is duplicated in the name of "specialized" needs. Some of this duplication could be eliminated by the standardization of certain curricular requirements agreed upon by businesses with similar activities, and resource-shared using communicative media.

3.3.2 Re-training.

The rapid change of technology in the economic market often requires professional re-training for new careers. Using the work setting can be a positive way of motivating workers to re-train for jobs within the company or outside. Re-training course materials could be purchased by the company from an accredited re-training company and received at the

3.3.2 --Continued.

company work site through low cost educational satellite transmissions.

3.3.4 Problem Solving.

Problem solving in business and government can be helped using direct multi-participatory communicative links. The "conference call" technology is extremely primitive and costly in today's communications structure.

3.3.5 Information Systems.

Library services for businesses based on large scale communications capability can interface with educational facilities to share research capability. The university is provided with the practical information of the professional community while the business community is linked to the theoretical and academic resources of the university.

3.4 Social and Leisure Applications.

As leisure time increases in a society, educational activities become an extremely important part of the life process.

3.4.1 Games.

Games of all varieties can be used to teach as well as entertain and some social structures evolve into peer groups that stimulate other learning activities, for example, Star Trek games, chess societies, and athletic leagues. Enhanced communications and resource-sharing can make game playing and peer group development far easier, more rewarding, and a larger force for leisure activities.

3.4.2 Group Activity Support.

Like gaming, encouraging leisure peer groups can enhance the social experience of individuals if the communications can be maintained at a reliable and inexpensive level.

3.5 The Religious Setting.

Although the constitution expressly separates church and state, religious education is a large component of overall educational activities in this country. It is mentioned in this scenario to illustrate the fallicy within the context of space industrialization of assuming the necessity for a "non-profit" approach to educational satellite usage. If the user community is sufficiently large and the cost of system utilization is reasonable, a specific user community (a part of the total community) can use the system at the lower commercial rate. Religious education is just such a component of overall educational satellite usage.

3.5.1 Scenario.

A religious denomination leases satellite time for special series of historical lectures to be broadcast to all Sunday schools within a given time zone, and to remote church and missionary locations. Interaction channels are available for teachers and students to interact with resource discussion leaders at the denomination's seminary after each broadcast.

4.0 Areas of Impact (International).

The aerospace industry is one of the few United States industries which does not suffer a penalty in the international market from this country's high development and labor costs. Technical expertise effectively makes the United States a "sole source" for advanced aerospace systems including spaceborne hardware. Present leadership in communications and computer technology and the coming on-line of the space shuttle reusable launch system makes space an attractive area for United States stimulated international development and potential exportable goods and services. LSS for communications purposes have three basic advantages for both developed and emerging nations:

1. The ability to distribute signals over wide geographical areas,
2. The reduced cost of satellite communication systems versus installation of land based systems,
3. The ability of a communication satellite system to create instant educational networks.

4.1 The International School and Home Setting.

In emerging nations, one of the most pressing needs is the impartation of basic skills.

4.1.1 Reading and Writing.

The ability to read and write is fundamental for a society engaged in industrialization and economic development. Reading and writing also enhances a nation's ability to communicate its own culture and address specific national problems.

4.1.2 Mathematical Concepts.

Modern societies are based on monetary exchange systems and machinery which require the use of applied mathematics. Mathematical education above simple numeration processes is essential to a developing country.

4.1.3 Technological Awareness.

Those countries who have been most successful in economic development have a population with a certain level of technological awareness or the ability to interact with technology in a constructive way. It is a unique challenge to make people at once both technologically aware and socially responsible to the obligations and culture of their country. This can be accomplished using an educational system which stimulates technological understanding within the framework of a nation's intellectual and cultural milieu.

4.1.4 Career Education.

Developing countries can use satellite broadcast programs to teach career skills and demonstrate requirements for different career fields. Rural areas can receive job and training information which could create industry in the countryside or prepare them somewhat for the urban job market.

4.1.5 Environmental Problems.

Responsible technological development requires an understanding of the effects of technology on the environment. All nations can encourage development with an environmental awareness resulting in more positive industrialized outcomes. For example, the HABITAT conference held in Vancouver, British Columbia, Canada in 1976 had many examples of local materials being applied to meet human habitability requirements. Many of the programs were accomplished by participation between the government and the local populations through interaction and educational training.

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4.1.6 Social Development.

Various United Nations conferences predict increasing stability and quality of life. This will only be possible if the educational systems keep pace and stimulate positive social growth. Educational media distributed by satellites in the form of cultural programs and social programs can provide some of this stimulus.

4.2 Skills in the Job Setting.

4.2.1 Job Training.

In addition to basic skills, specific job training courses for workers in obsolete professions can be carried out using satellite systems similar to those mentioned in the domestic scenario (Section 3.3).

4.2.2 Upgrading.

Continual development beyond the acquisition of technical job skills will be necessary to maintain development levels in emerging nations and developed nations.

4.3 Social Interaction.

An educational communications system based on the model outlined provides a vehicle for both societal change and intersocietal exchange of cultural and practical information. With governmental security and controls provided by coding techniques, interaction within a society can be carried on in a non-threatening manner and even international interaction can occur within controlled limits. If man inhabits a "global village" then communication is essential if men are to interact and understand each other. A large space communications structure equipped for interpersonal interaction as well as educational program broadcasting capability provides a powerful tool for elevating the "have-nots" to a point where they can

4.3 --Continued.

begin to compete with the "haves". Costs for less productive educational systems would actually be more prohibitive than costs for educational satellite program distribution.

4.4 Implementation.

Promotion and marketing of large communications satellites for use by foreign countries for educational and communications purposes could be accomplished as outlined in the following sketch.

4.4.1 United States Demonstration.

Using space shuttle and LSS technology developed in the early 1980's, a large communication satellite can be constructed and put into service by the mid 1980's. This satellite would serve as a test bed for distribution, utilization, and operations problem solving, and can be moved around the world for on-site demonstrations and international participation similar to the ATS-6 project, but planned in a stepped way to allow the participating government to purchase the demonstration materials for later use. The cost of the project would be borne by government and industry sources, and the satellite would be put into commercial service upon completion of the demonstration experiments.

4.4.2 International Model.

Funding from fiscally capable foreign governments and/or the International Monetary Fund would then be procurred to build an internationally owned communications satellite with United States aerospace corporations acting as contractors and NASA acting in a cost-reimbursable launch capacity. The international model would be put in commercial service for the purchaser complete with ground and software support. Based upon these first two models, production schedules, amortization

4.4.2 --Continued.

costs, and maintenance costs could be established. These activities could easily occur in the 1985-1988 timeframe.

4.4.3 Production Facility.

With the fabrication of the first domestic models and international purchase, ground based construction facilities could be established in this country with active marketing programs pursued through corporate channels. Educational activities which are intensive in time utilization and system utilization can be absorbed in with the cost of normal commercial activities, or supported wholly by governments whose populace is too poor to participate, or supported by low cost user utilization in countries where the population has sufficient capital resources to invest in its own education. Countries owning large communications satellites can also sublet transponders for use by neighboring countries at commercial rates helping to reduce the overall purchase and operational costs of the system.

4.4.4 Software Planning.

Educators and technicians from the United States can be assigned as working groups by academic subject area to help purchasing countries establish viable educational programs. Technical support would also be made available for operational assistance and maintenance assistance.

5.0 Derived Marketing Opportunities (Domestic and International).

5.1 Satellite Services.

The following product/services can be offered in conjunction with large scale educational communications satellites:

5.1.1 Ground Fabrication.

The satellite would be fabricated and assembled by the contracting aerospace corporations and sub-contractors.

5.1.2 On-orbit Services.

Construction services on-orbit would be provided for the purchased LSS communications satellite structure.

5.1.3 Payload Launch Services.

Re-imbursible shuttle flights would be flown to provide construction and maintenance of the satellite structure.

5.1.4 Development Services.

International development capital would allow countries to initiate purchase of LSS communications facilities to be repaid through amortization collected from communications and educational applications.

5.2 Transmission and Ground Support.

Associated with transmission equipment for educational program distribution, the development of compatible product lines of transmitters, receivers, and transceivers would be attractive as marketable items. N.B. This type of product would generate quick international competition for the market-place.

5.2.2 Coding Devices.

As outlined in a previous section (2.3.3) the necessity for political integrity, privacy, user analysis, etc., would make coding devices a critical element for the acceptability of LSS communications systems on the international scale and even an important factor in domestic usage. Coding devices such as magnetic card keys, solid state devices, or simple frequency modulation control can provide creative new areas of development for the technology of peripheral security devices. The decade of the 1980's could see an explosion in the communications privacy industry as low cost electronic devices are introduced.

5.2.3 Antennae.

For those systems not supplied by cable or fiber optics and having wide geographical dispersion, low cost receiver-antenna systems would have to be commercially available. Depending upon the frequencies allocated for specific functions, these antennae could be made to different tolerances at different costs. Again, international competition can be high in this area of the marketplace, but the worldwide market is so potentially large that development and sales would form the basis of an entire industry.

5.2.4 Video/Audio Compressors.

Video and audio compression is a promising technology which would multiply a satellite's capabilities by reducing the time a given signal impacts on the satellite system for a corresponding real-time playback. Presently, the equipment is bulky and complex, but a breakthrough in compression techniques would provide broadcast facilities, businesses, and even individuals with the ability to transmit substantial quantities of video and audio information extremely rapidly and economically.

5.2.5 Studio and Broadcast Facilities.

Creation of customized educational programming is a complete industry. Each country would require specific production and broadcast facilities to support its educational efforts. Supplying equipment for such studies can be of itself a highly competitive international market. It can also enhance the sale of peripheral electronic devices to make conventional equipment compatible with the requirements of satellite broadcast. Examples of these peripheral devices: video compression equipment, studio controlled broadcast quality device (like VIR), studio coding devices, alphanumeric and other graphic production devices.

5.3 Data Processing.

Computer Assisted Instruction and Computer Managed Instruction can involve extremely complex ground support facilities and use a great deal of network time. Yet, that technique for instruction is a powerful tool for teaching basic skills to reasonably motivated studnets at an individualized rate. To accomplish this, many DP products for the mass market would be necessary.

5.3.1 Computers.

Educational computers would require high density memories for course and library materials, and different systems would be needed for different countries and even different program areas.

5.3.2 Peripherals.

To tie the computers together requires Input/Output devices (IO) from the user through the satellite to the CPU. Extensive computerized instruction would require a proliferation of low cost terminals and microprocessors capable of editing data, and remote batch activities if the terminals are to service users in wide geographical areas.

5.3.3 Networks.

Effective DP networks have certain practical limitations in CPU capability which must be buffered by nodes and supervisor systems. Extensive use of far flung computer networking services will provide increased markets for network communications technology, minicomputer. and other interfacing hardware and software. This area is also open to foreign competition but DP equipment is still an area in which the United States is internationally competitive. Proliferation of the computer to the personal level connecting the user into networks for communications and educational purposes is a market that is only beginning to unfold with great growth potential.

5.3.4 DP Software.

CAI and CMI differentiated for different nations and user levels would require extensive software development. Pre-developed packages could be marketed readily creating a large software service need. Regionalized and even localized programming and custom programming services could also be marketed in areas where there is no technological base for software development.

5.4 Educational Software.

The area of software in education involves both prepared AV educational media and instructional computer software.

5.4.1 Computers.

Software in computer applications would include library and research programs which could be accessed through the network.

5.4.1.1 Library Services.

Library and research services provided at low cost would account for a great deal of system utilization.

5.4.1.2 Curricular Services.

As outlined above, CAI and CMI curriculum can be prepared and customized for individual users. To accomplish this purpose in the many required subject areas, massive software development programs would have to be initiated and continually updated.

5.4.2 Other Educational Media.

Classified under educational software are a variety of other educational media which are highly marketable.

5.4.2.1 Texts.

To support satellite educational activities, textbooks and workbooks based on television, radio, and computer coursework can be marketed. In a large scale national educational communications systems, the large markets are readily accessible by the publishing industry. Internationally, as in states in the United States, approval of text material by regulatory or supervisory agencies could result in enormous text sales. The marketing becomes simpler as the population increases and the selection agency is more centralized.

5.4.2.2 Prepared AV Media.

Educational entrepreneurs can sell various prepared media (slides, film video segments and other visual and audio peripherals) for electronic distribution as teaching aids for audio or video production. These educational data banks could be used as production modules to create the programming most suited to special educational needs. Such software could be leased or purchased based on marketing and copyright agreements.

6.0 Resulting Job Opportunities (United States).

6.1 Manufacturing Jobs.

The construction of a space industrialization communications system will involve extensive manufacturing capability.

6.1.1 Space Hardware.

Large space structure communication satellites will have to be fabricated on the ground for deployment in space due to the high cost of manhours in the space environment. While subsystems could be contracted to international agencies, final launch and assembly responsibilities would probably occur in the United States.

6.1.2 Ground Support Systems.

Emphasizing educational applications, ground support systems to utilize a satellite for supply of commercial services would include television studios (which may or may not already exist), large computer systems, urban video distribution systems, and data processing support hardware.

6.1.3 User (Consumer) Products.

Low cost products for the home or institutional user which must be manufactured and mass marketed include the antennae, audio and video transmitters, video cameras and microphones, computer terminals, data cassettes, and microfilm materials. These tools link the user with the satellite system to participate in educationally related uses as outlined in previous sections.

6.1.4 Supplemental Products.

To supplement educational activities, books, other published materials, and various data storage devices such as audio and video recording devices, would enhance user participation in the educational satellite networks. The size of the market for manufactured products is proportional to the satellite's user capability and inversely proportional to product cost.

6.2 Support Service Jobs.

Operation of a successful educational satellite system will create support service jobs in several areas.

6.2.1 Teachers.

6.2.1.1 Media Teachers.

To supply the necessary programming for education activities, whether school, homework, or leisure-oriented, a cadre of teachers able to interact successfully through remote media will be essential. Such teachers will require a feel for media production and an appealing media personality.

6.2.1.2 Resource Personnel.

Teachers for educational networks will be required to act as resource personnel to other teachers and to interpret the work of the media teacher to group and discussion leaders. They are the in-service specialists buffering the media teachers and the group and discussion leaders.

6.2.1.3 Group and Discussion Leaders.

Large numbers of part-time and full-time teachers with educational training will be required to input into peer groups, to be available as two-way interactive resource, to provide stimulating follow-on discussions, and to provide guidance to users of the educational network services.

6.2.2 Audio-Visual Production Personnel.

Substantial numbers of educationally oriented audio-visual production personnel will be required to create the necessary support programming to be marketed for educational purposes. This will include television and radio production capabilities and the ability to translate the communicative media into viable and reliable educational formats.

6.2.3 Computer Services.

6.2.3.1 Programming.

Educational services provided by network utilizing computers will require a cadre of programmer-educators capable of creating curriculum to be used and administered in computer form. These educators will create CMI and CAI both compatible with and independent from broadcast courses.

6.2.3.2 Resource Personnel.

Interactive personnel must be available via network to buffer the individual user and the network, answering questions and providing operational network guidance. Like the group and discussion leaders, many of these people can be university students and graduate students who work part-time at moderate pay, or housewives, or inactive teachers who would like to maintain some level of part-time or even full-time connection with the educational process.

6.2.4 Maintenance.

As outlined previously, extensive sales of computers and audio-visual receiving and transmitting equipment will require extensive maintenance networks to support leasing and purchase agreements of educational equipment. Much of the maintenance can be accomplished through manufacturers of the material but regional maintenance centers, which can handle

6.2.4 --Continued.

virtually any compatible system hardware, will make it much easier for the public to acquire and service some of the new components which they will need to participate in the system.

6.2.5 Library Services.

A truly large scale interactive network capable of both audio-visual and data processing interaction offers extensive job possibilities in the area of library services.

6.2.5.1 Cataloguing.

Assuming ease of access into a large scale educational library system, cataloguing to keep pace with the geometric growth of publication and knowledge will involve hundreds if not thousands of professional librarians. Even continuous use of these services may not pay for the expense to be incurred in cataloguing the incredible amount of publishing, but some of this cost can be absorbed by the individual user, government, industry, and university consortia.

6.2.5.2 Bibliography.

To provide ready research services, on-line bibliographical librarians will be required. Some searches can be accomplished by using data processing sorting techniques but other researches will require human input.

6.2.5.3 Research.

Like bibliographical compilation, individual interaction will be required for many research needs. This will require the availability of competent research librarians trained to interact via data processing and audio links.

6.2.5.4 Special Features.

Another library category will involve culling through incoming materials to identify special features of general interest, special calendar events, special programming, and literary arrivals. This service, sold as a magazine by subscription, will allow an educational satellite system user to scan events prior to selection of educational activities.

6.2.5.5 Inter-library Loan.

An extensive library network eliminates much of the necessity for inter-library loan; the librarians will be required to supervise the sharing and access of data banks for usage, evaluation, and billing purposes.

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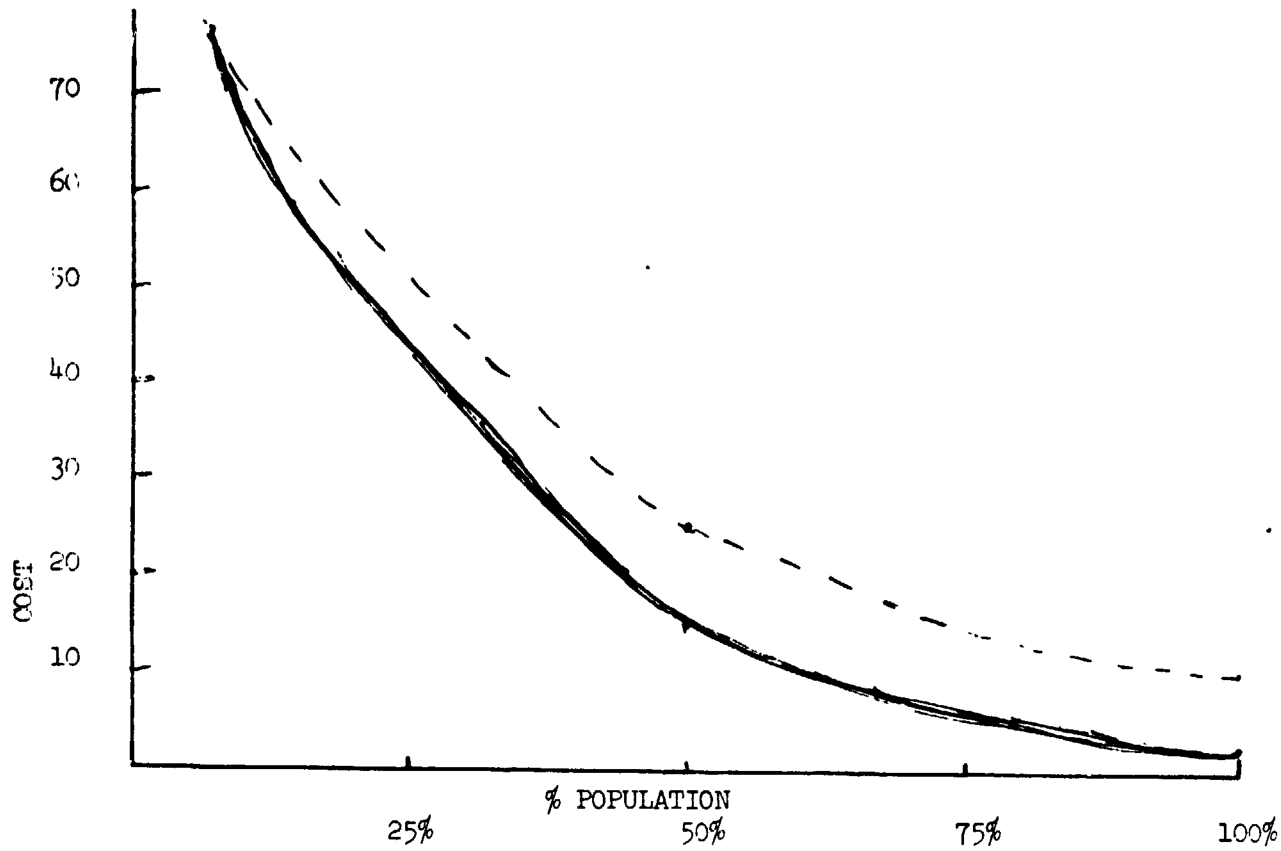
APPENDICES

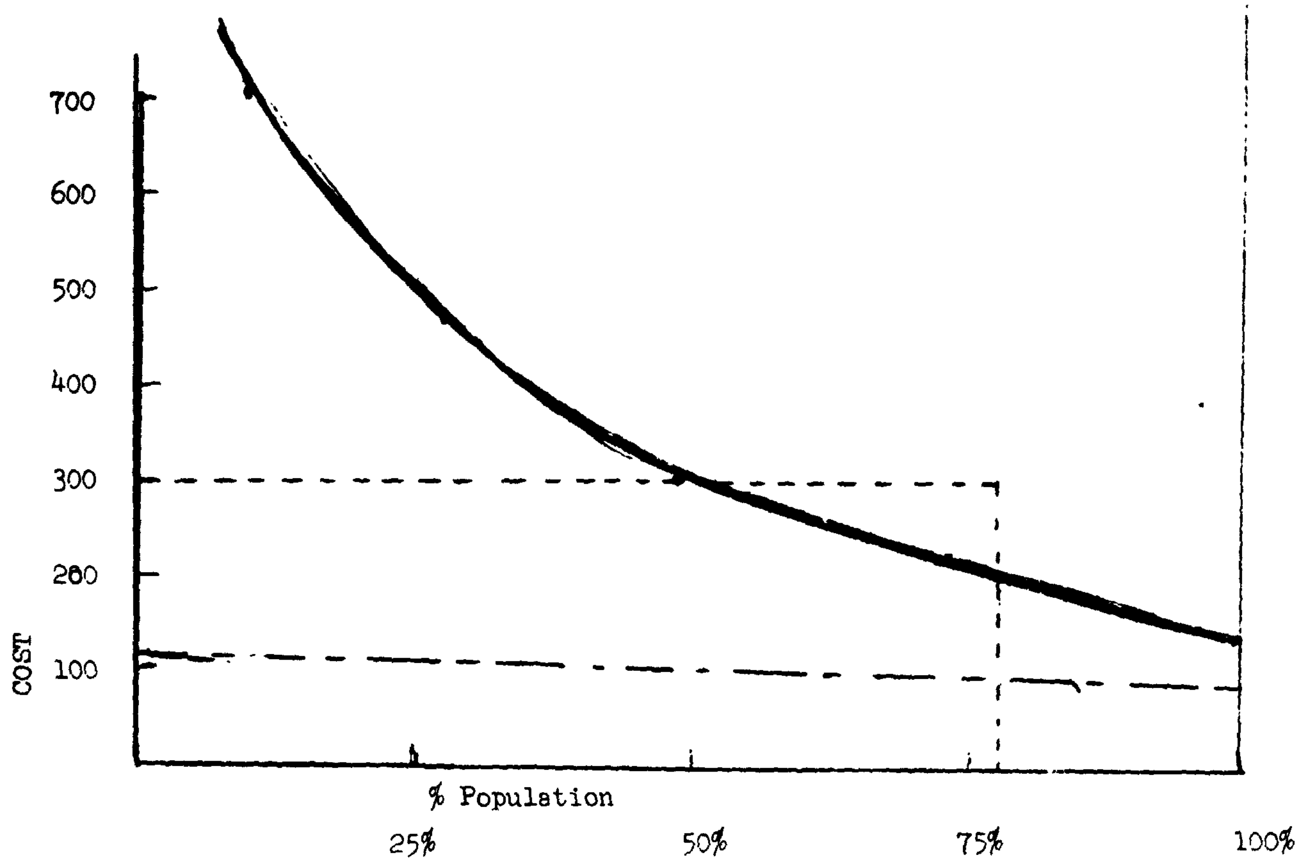
COST OF COURSE VS. % POPULATION AFFORDABILITY



——— % affordable to total Educational Population (Age 3-Adult)

- - - - % affordable to continuing Educational Population (16-Adult) km.j

RECEIVER/ANTENNA COST VS. % POPULATION AFFORDABILITY



(Based on variable antenna cost)

(Based on antenna cost (ATS-6 technology) of $200)

(Based on anticipated cost (Large Space Structure) of 25)
TV Receiver (B&W) at $100

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CONTINUING EDUCATIONAL TELEVISION VIA SATELLITE
DISTRIBUTION SYSTEM
COST PARAMETERS

Production: (TV)

Standard ETV: $5000/hr

Subsidized (donated services at commercial production rates) as low as $1000/hr

Elaborate Production (Sesame Street) $48,000/hr

Overseas: Japan $2500/hr
El Salvador $1300/hr

(RADIO) $1000/hr

Transmission: (TV) ATS-6: $1000/hr

WESTAR: $1.2-2.17 million/yr (1 transponder)

(RADIO)
2-way
INTELSAT $ 13,000/½circuit/yr (Jan. 1972)
WESTAR $ 13,440/circuit/yr (NY-L.A.: Spring, 1975)
$ 7.440 " " (NY- Atlanta)

kmj

COST DRIVERS

ETV PRODUCTION

BROADCAST (SATELLITE & GROUND FACILITIES)

DISTRIBUTION (USER POPULATION)

RECEIVER (RADIO/TV + ANTENNA)

C= Cost per Student per Hour

P= Production Cost ($5000/hr)

B= Broadcast Cost ($1000/hr)

R= Receiver (TV/Radio+ Antenna/hrs. of use) (approx. $.09/hr)

n= User Population (Distribution of Programming)

$$C = \frac{P + B}{n} + R$$

Population (n)	Cost (C)
10^2	$60.09
10^3	6.09
10^4	.69
10^5	.15
10^6	.096

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S.I.E.

EDUCATION & SUPPORT JOB OPPORTUNITIES

MANUFACTURING:

- ANTENNAE
- XMTRs (AUDIO & VIDEO)
- CAMERAS/MICS
- TEMINALS
- DATA CASSETTES
- MICROFILM

- PRINTED MATERIALS (PUBLISHING)
- DATA PROCESSING SUPPORT HARDWARE
- SUPPORT FACILITIES

S.I.E.

EDUCATION & SUPPORT JOB OPPORTUNITIES

SERVICES:

- TEACHERS:
  - GROUP & DISCUSSION LEADERS
  - RESOURCE PERSONNEL (PROFESSIONAL NETWORKS)
  - MEDIA TEACHERS
- AUDIO/VISUAL PRODUCTION PERSONNEL (& SUPPORT)
- COMPUTER SERVICES (CMI & CAI)
- MAINTENANCE
- LIBRARY:
  - CATALOGUING
  - BIBLIOGRAPHY
  - RESEARCH
  - FEATURES
  - INTERLIBRARY LOAN (DATA BANK SHARING)
  - D.P. SERVICES

Table 6

Elementary and Secondary Education Instructional Needs

PUBLIC SERVICE COMMUNICATIONS USER REQUIREMENTS						
		USER TERMINALS				
Application	Service Type	Description	No.	Geographical Distribution	Information Volume	Remarks
Elementary and Secondary Education Instructional needs of elementary	Written Messages Slow-Scan Video Audio	Audio Transiever Computer Terminal 2-way Video (Color) Telecopier Teletype Video Tape	65,000 Fixed, 1,000 Mobile	NATION-WIDE: Figures are based on the number of schools in the U.S. (65,000). These are minimum amounts and do not	The system should be operational 7 hours per day, 5 days a week: Total of 35 hours per week.	A. A system with this configuration will: 1) Enable the classroom teacher to: a) have independent access to instructional programs and resources when needed.
and secondary students	Simplex Duplex Facsimile Radio Computer	Recorder Multi-Channel Capability		take into consideration the number of students and teachers this system will service.		b) have remote access to specialists to aid in the diagnosis of educational problems of their students. c) obtain immediate access to remotely stored instructional materials, resources, and programs.
	Information and Data Television Television and Two way audio					d) provide computer assisted instruction for their students. e) use multi-channel capability to provide differentiated instruction for various ability groups. f) to obtain expert consultation
	TV Teleconferencing					services related to educational problems. 2) Provide students with opportunities: a) to see/hear/participate in special events that have limited appeal to commercial media.

Table 6 (continued)

PUBLIC SERVICE COMMUNICATIONS USER REQUIREMENTS

Application	Service Type	USER TERMINALS: Description	USER TERMINALS: No.	USER TERMINALS: Geographical Distribution	Information Volume	Remarks
						b) for computer assisted instruction (CAI) that will enhance individualized instruction and increase efficiency of teacher/student instructional time. 3. With mobile receiving terminals, a system such as this can also be used to provide temporary instruction for home-bound students or long term instruction for students who require an alternative to public/private school instruction.

Table 7

Elementary and Secondary Teacher Education Needs

PUBLIC SERVICE COMMUNICATIONS USER REQUIREMENTS						
		USER TERMINALS				
Application	Service Type	Description	No.	Geographical Distribution	Information Volume	Remarks
Teleconferencing for Teachers & other Educators 4 M	Audio/Video Multiple Simultaneous Terminals	2-Way Voice/Video RO Terminals	1 per 300 teachers	U.S. 50 States and the Territories	2 hour transmissions 5 days/wk	Need: for legislative briefings; Bd. of Dir. Meetings; Public policy reeducation; interviewing public officials Inner-Assoc. Communication, Education & Related Professions.
In-Service Courses for Teachers & Other Educators 4 M	Video RO Audio 2 Way Color; Digital Data	School house terminals - 1 per each school building	NA	U.S. 50 States and the Territories	5 courses/wk (1 hour each course, 3 times per wk)	Need: for Professional growth & Development of teachers re: instructional matters re: cultural interchange (National & global) re: Expert consultation re: home instruction for teachers.
Telex-Mailgrams Telegrams	Data Link	500/day to the field 500 day from the field	Each state and regional office and central office	U.S. 50 States and the Territories	130,000 Telexes Mailgrams, Telegrams	Need: Intra-Association Communications Ex.: NEA AASA etc. (See: NEA Model Attached)

Table 8

Professional Development Needs

(Prototype of requirements of one national professional teachers association)

School districts: 17,000
School buildings: 65,000
Professional org.: N/A

PUBLIC SERVICE COMMUNICATIONS USER REQUIREMENTS						
		USER TERMINALS				
Application	Service Type	Description	No.	Geographical Distribution	Information Volume	Remarks
Teleconfer-encing for Teachers	Audio/Video Multiple simultaneous Terminals	2-Way Voice/Video RO terminals in NEA regional offices Present Planned Needed (1 for each 1200 teachers)	 0 0 2,000	U.S. 50 States and the Territories	2 hour transmissions 5 days/wk	Need: for legislative briefings; Board of Directors meetings; UNISERV training sessions
In-Service Courses for Teachers	Video R0; Audio 2 Way Color; Digital Data	School house terminals - 1 per each school building Present Planned Needed	 0 0 65,000	U.S. 50 States and the Territories	3 courses/wk (1 hour each course, 3 times per wk)	Need: for professional growth and development of teachers
Telex Mailgrams, Telegrams	Data Link	25/day to the field 25/day from the field Present Planned Needed	 0 0 2,000	U.S. 50 States and the Territories	[illegible]0 Telexes Mailgrams, Telegrams	Need: Intra-association communications
Data Transmission Computer Uses	Video, R0 Audio 2 Way Digital Data	NEA UNISERV offices nation-wide Present Planned Needed	 0 0 2,000	U.S. 50 States	50[illegible] uses daily	Need: Research data, membership surveys

Table 9

Information Storage, Distribution and Utilization of Materials and Resources

PUBLIC SERVICE COMMUNICATIONS USER REQUIREMENTS						
		USER TERMINALS				
Application	Service Type	Description	No.	Geographical Distribution	Information Volume	Remarks
Storage Retrieval Distribution and Utilization of Educational Information	2-way digital 1-way audio 1-way video 1-way facsimile	Input/Output terminals with print-out capability; audio, video, and facsimile read out capability	65,000	1 in each school	Available on demand could possibly be processed after school hours.	Information to be stored: 1. Student data 2. Programs of studies 3. Instructional Objectives 4. Learning activities 5. Learning modes ~~6. Media Resources~~ 7. Measurement Instruments 8. Diagnostic/Remedial procedures 9. Management Information

Table 10

Public Information Needs

PUBLIC SERVICE COMMUNICATIONS USER REQUIREMENTS						
		USER TERMINALS				
Application	Service Type	Description	No.	Geographical Distribution	Information Volume	Remarks
Inter-school teleconferencing with home-viewing	2-way video 2-way audio video	Audio/video receivers in regional sites Video receiver in each home	65,000	50 U.S. States	60 min. each week or 30 min. 3 x/wk	Method Regional active participation by schools. Home viewer participation via phone to regional site if desired. Purposes 1. To aid parents in dealing with their children 0-18 years. 2. To develop public participation in educational policy.

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Table 11

Program Development and Evaluation Needs

PUBLIC SERVICE COMMUNICATIONS USER REQUIREMENTS						
		USER TERMINALS				
Application	Service Type	Description	No.	Geographical Distribution	Information Volume	Remarks
Additional program development and selection of programs Elementary and	Video/Audio	Point to Point Video School Terminal for U.S.A.	65,000	U.S. 50 States and the Territories	8 a.m. - 3 p.m. Mon. - Fri. 180 days of school 1260 hours	Need: Increased delivery of nonprint curriculum in addition to present PBS system. The volume of program activity prohibits viewing because of the last of delivery systems and access to products. Most stations could
Secondary Schools						provide double their present delivery if there were more space available.
Additional program development and selection of programs for parents of students	Video/Audio	Point to Point	PBS	Station 200 Commercial Networks 200 35,000,000 students Approx. 12 million homes U.S. 50 States	3 hours per week 156 hours per year	Need: For increased understanding by parents of the educational curriculum used by schools
Additional program development and selection for pre-school early childhood grade level 2-4 years old	Video/Audio	Point to Point Video for U.S.A. Day Care Centers or Home Market	10,000 (approx) 4 million homes (approx)	U.S. 50 States and the Territories	Potential capacity 3 hours per day 1000 hours per year	Need: To provide additional pro-social program material for pre-school children

Table 11 (continued)

PUBLIC SERVICE COMMUNICATIONS USER REQUIREMENTS						
		USER TERMINALS				
Application	Service Type	Description	No.	Geographical Distribution	Information Volume	Remarks
Target Audience programming in Elementary and Secondary Education	Video/Audio					Need: Provide special programming to target groups for equal educational opportunity in school districts, - minority ethnic - special education - vocational education
a) Block and Spanish **b) Special Education** **c) Vocational Education**		Point to Point Major urban areas 10,000 school buildings	65,000 school bldgs.	50 States 50 States	2 hours per day Mon - Friday @ 180 days per year 1,800 hours 6 hours per day 2,190 hours per year	
			10,000 school bldgs.		4 hours per day 720 hours per year	
Five Programs Simulation example - Toronto Moon Vigil	2-way Video/audio	Regional groups interconnecting with PBS stations by terrestial lines. Elementary and Secondary Schools	6 up-links 150 re-ceivers	50 States	2 hours per week 50 hours per year	Need: The sharing and collaboration of key educational professionals in a broad geographic area

Table 11 (continued)

PUBLIC SERVICE COMMUNICATIONS USER REQUIREMENTS						
		USER TERMINALS				
Application	Service Type	Description	No.	Geographical Distribution	Information Volume	Remarks
USER involvement in program production and public participation in program	2-way video/audio	NEA Regional Officers Teachers - PBS Stations or Regional Networks	 2,000 150 5	50 States	2 hours per week (realistic potential) 50 hours	Need: Involvement by users of product to participate in program planning of the development of curriculum product
policy		Example: Eastern Educational Networks.				
Teleconferencing for variety of Associations and audiences a) teachers b) supt/	2-way video/audio	Point to Point Confering Maximum 20 Participants for groups terminals	 20 20	50 States	Depends upon availability Potential 1,000 hours per year.	Need: Establish better lines for communication; bringing together groups from large distances without necessary travel expenditures.
administrators c) students			 20			

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F. EMPLOYMENT IMPLICATIONS OF ALTERNATIVE GOVERNMENT PROGRAMS

APPENDIX F:

EMPLOYMENT IMPLICATIONS OF ALTERNATIVE GOVERNMENT PROGRAMS

(A paper prepared by T. A. Gibson, Senior Economist,
Government Affairs, Space Division,
Rockwell International Corporation, April 1975)

EMPLOYMENT IMPLICATIONS OF ALTERNATIVE GOVERNMENT PROGRAMS

EXECUTIVE SUMMARY

The allocation of resources among competing uses is a central problem in developing and implementing public policy. It is therefore necessary to establish meaningful criteria for measuring the value of alternative programs so that a basis for achieving optimum use of limited resources can be established. But there seems to be a tendency on the part of a few policy makers and opinion leaders to establish unrealistic criteria for these purposes. Critics of the space program who argue for reduced funding by claiming that outlays for space create fewer jobs than other types of spending fall into this category.

The proper view is that the purpose of the space program and nearly all other public programs is not job creation per se, and that allocative decisions on these programs should more appropriately relate to their primary goals. To argue the merits of space on the basis of jobs diverts attention from the real purposes and benefits of the space program. But the issue of jobs is increasingly voiced by space antagonists, and a response is therefore in order.

All public spending programs create or sustain jobs unless the economy is fully employed at the outset, for recessions and high unemployment are caused by insufficient aggregate demand (total spending) in the economy. The arguments of the critics, however, seem to be that space spending is relatively inefficient in this respect. This theme is discernible in three forms:

1) income transfer programs, the category into which most income security and other social programs fall, usually generate more jobs per outlay dollar than government purchases, the category into which the space program falls

2) space spending diverts resources from programs that create more jobs than the space program

3) implicitly, the main concern of public policy should be with near term conditions, and outlays for programs of a social nature create more immediate and near term jobs than outlays for space.

The first argument will be shown to be highly questionable, and the facts do not sustain the second one. Parts of the third, however, have superficial validity, but it completely ignores longer term considerations. Each of the arguments can be briefly assessed as follows:

1. <u>Transfer programs vs. government purchases programs as job creators.</u> In comparing equivalent increments of spending for transfers and government purchases, say $1 million, it must be kept in mind that some fraction of the transfers, albeit a very small one, will find its way into savings and thus will be withheld from the spending stream at the initial round of spending. This is true because transfers do not represent direct purchases of output. Instead they are merely redistributions of income by the government to bolster the incomes of the recipients. Thus rather than $1 million

immediately buying goods and services, creating direct jobs and setting off a chain reaction of secondary buying and indirect jobs, some amount less than that will be initially injected into the spending stream by the transfer recipients.

In the case of government purchases, however, there is no initial leakage and the full \$1 million is spent at the outset. Thus conceptually, government purchases tend to create more jobs than transfer payments simply because the initial increment of spending is higher. In fact, it can be shown that theoretically, government purchase multipliers are exactly one more than transfer multipliers - if the latter is two, the former is three.

There are many qualifications to this line of reasoning, the most obvious one being that transfers usually go to people in lower income groups who tend to spend more and save less of their income increments, i.e., they have a higher marginal propensity to consume. To the extent this is true, the multiplier differentials between purchase and transfer programs will be somewhat less than one. But the point is that a sound case can be made favoring government purchases as being more efficient in stimulating spending and employment than transfers.

Perhaps of greater significance than the refutation of this "pro transfer" argument used by space critics, however, is to point out that it is superficial. It applies only to the short term, and it erroneously assumes that the space program is a serious competitor with social programs. Furthermore, it fails to relate to the primary goals of the programs falling into either the purchases or transfer spending categories.

2. Space spending diverts resources from other programs.

Those who urge reductions in space spending inevitably argue that with less spent on space, more will be spent on the programs they support, thereby better serving the national interest including, of course, the g l of full employment. But there is little evidence to sustain this position and those who so argue have little understanding of the political economy of federal budget making.

Recent experience with income security and health programs is fairly typical of outlay trends for all social programs. From FY 1966 to 1974, when space spending declined from $5.6 billion to $3.0 billion, annual outlays for federal income security and health programs rose from $31.5 billion to $106.5 billion - an increase of $75.0 billion. Whereas spending on space in FY 1975 will remain at approximately the $3.0 billion level, outlays for income security and health programs are expected to rise to $133.2 billion. In this year alone, then, expenditures for these programs will have risen by nearly $27 billion. In light of this evidence, it is impossible to argue convincingly that the space program has diverted funds from social programs.

3. <u>Outlays for public works, public service employment and other social programs create more jobs than space outlays.</u>

This argument elicits the real substantive issues involved in the overall question of the employment effects of public programs. Those proffering it make their estimates by assuming the total number of jobs created is the quotient obtained by dividing a given outlay by an estimate of the average annual wage of the workers involved. Obviously their analysis concludes that more immediate jobs are created if the productivity and therefore the average wage of workers on a program is lower than if the workers enjoy higher wages.

This narrow approach is deficient, however, in that it ignores the important qualitative and longer term quantitative aspects of the job issue. It is important to adopt a balanced approach to employment policy lest we sacrifice our option for a viable and fully employed future economy by taking short term measures that starve programs capable of creating productive capacity. With this in mind, space activity has greater potency in creating future employment than most programs advocated by its detractors. The logic chain is straightforward: economic progress (improved productivity and economic growth) is necessary to meet future employment needs of a growing labor force, technology is the chief source of economic progress, and space research and development is an important source of technology that contributes directly and indirectly to higher productivity. Therefore adequate support to space R&D activity contributes in a significant way to solving the nation's employment problems.

Concluding Remarks

It is a fact that high technology activity like the space program adds to the nation's productive capacity and results in productivity gains to a far greater extent than most of the social programs. This doesn't mean the latter are unjustified, but if we are to have an approach balanced between current and future needs, if we want to establish the basis for a fully employed labor force in the future, we can ill afford to further reduce current outlays for space and other high technology activity. The social costs of inadequate support for space are not just the immediate loss of jobs occupied by scientists, engineers and skilled technicians, but the potential loss to the nation's productive capacity and its ability to accommodate growth and a sufficient employment base in the future.

EMPLOYMENT IMPLICATIONS OF ALTERNATIVE
GOVERNMENT PROGRAMS

INTRODUCTION

Recent efforts to escalate to the status of a major issue a comparison of the quantitative aspects of space program employment with the job creation ability of other programs constitute a most unfortunate trend. Such digressions divert attention from the real purposes and benefits of the space program. As in the case of all but an infinitesimal number of the thousands of programs conducted by the federal government in the public interest, job creation is a result but not a specific purpose of the space program. The few current examples of public programs at the federal level whose chief objectives are to create jobs are mostly found in the public service employment category. But these are emergency measures specifically designed to provide jobs on a temporary basis in periods of high unemployment. Nearly all other government programs, whether in support of public policy in the economic, social, foreign or defense realms, have different primary purposes. Debates and allocative decisions on these programs should, therefore, relate to their primary purposes, and each program, including space, should be measured against criteria based on these principal objectives.

This point was made in a recent report prepared by the staff of the Committee on the Budget, U.S. Senate. In discussing the job creation and other fiscal implications of alternate government programs, the report stated that rather than assign differential economic impacts to alternative expenditure programs,". . . it is better to argue the issues of defense versus income transfers in terms of need for national security and the need for income redistribution.

Similarly, considerations of international politics, not domestic macro-economics, should determine the level of foreign aid".[1]

The fact that space antagonists have raised the issue of jobs, however, necessitates a studied response. It is a simple arithmetic process to estimate jobs by dividing a proposed government outlay by an approximation of the average wage of the workers to be assigned to the program. This naive approach is becoming increasingly popular among critics of the space program, for obviously more lower paying jobs will be created in the short run for a given level of spending - the lower the average wage, the greater the number of jobs. But this is a narrow and unbalanced technique that ignores longer term considerations of the employment issue.

The purpose of this paper is to add additional dimensions to this issue by considering employment implications of alternative government programs primarily from a qualitative standpoint within a broader time frame than considered by the critics. It will be shown that as in most things, a balanced approach is necessary in coping with problems of unemployment, and that excessive reductions of high technology activities like the space program can seriously exacerbate future problems associated with achieving a full employment economy.

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[1] "Fiscal Alternatives in 1975." A Preliminary Staff Report, Committee on the Budget, U.S. Senate, 3 March 1975, p. 24.

Three basic areas relevant to the employment issue are explored. The first addresses the question of methods of funding public programs and their implications to employment levels. The second analyzes the longer term effects on income and employment of space and other high technology programs. And the final area reviews the claims of those who argue that the space program has diverted resources from social programs designed to deal directly with problems of unemployment and poverty. The first and third sections are included because they directly respond to oft-heard but fundamentally superficial views of some of the more outspoken critics of the space program. Usually overlooked by these critics are the more substantive issues developed in the second section.

TRANSFER PAYMENTS AND GOVERNMENT PURCHASES AS JOB CREATORS

A fundamental misconception exists in the minds of a number of critics of the space program with respect to the inherent job creation ability of various types of government spending programs. This most particularly applies to government transfer payments compared with programs involving direct government purchases of goods and services. Implicit in the views expressed by those who advocate reallocation of resources from space to income security or similar programs via the transfer mechanism, is the belief that more total jobs will thus be created. But this is not necessarily the case for reasons briefly developed below and in greater detail in the Appendix.

Federal sector expenditures can be thought of in terms of several major groupings. The three primary ones are purchases of goods and services, transfer payments, and grants-in-aid to state and local governments. Purchases are that portion of the nation's output of goods and services bought directly by the federal government. These purchases absorb output and are included in calculating the GNP (which includes only the value of goods and services sold to final users during a year). Transfers, on the other hand, do not in themselves represent purchases of output, but rather are payments by the government to individuals to bolster their incomes rather than to reward them for current productive services. They are merely redistributions of income among segments of society with the government acting as the transfer agent.

Finally, grants-in-aid outlays support programs designed to help state and local governments finance their own transfer activities and purchases of goods and services.

A major shift in federal expenditures has been underway for a number of years. This can be seen in Table 1. In 1965, purchases represented 54 percent of total government outlays - $64.4 billion out of $118.5 billion. Although increasing to $110.3 billion in 1974, purchases last year were only 40 percent of the total, and will represent only 37 percent this year. There has been a corresponding rise in the other components, especially in transfer payments which are estimated to exceed purchases in 1975. Transfers were only $30.5 billion in 1965, just 26 percent of total federal expenditures. This year they will approximate $132 billion, or 41 percent of the total. Combined outlays for transfers and grants are expected to be well over half of total federal sector expenditures this year. Indeed, they account for the bulk of the increase in federal spending in recent years.

Within the context of this paper, the fundamental question with respect to these federal spending trends is not the relative social merits of the programs each outlay mode supports. Disagreements certainly arise over degree, but few would deny the need for income redistribution programs of the type implemented by transfer payments in such areas as income security, health care, and veteran's benefits. The real issue here, however, is the frequently heard suggestion of using the transfer device as an employment stimulant. This effectively can be translated as meaning reducing

Table 1. FEDERAL EXPENDITURES IN THE NATIONAL INCOME ACCOUNTS

YEAR	PURCHASES OF GOODS & SERVICES		TRANSFER PAYMENTS		GRANTS-IN-AID		ALL OTHER OUTLAYS*		TOTAL OUTLAYS
	$'s Billions	% of Total	$'s Billions	% of Total	$'s Billions	% of Total	$'s Billions	% of Total	$'s Billions
1965	64.4	54	30.5	26	10.9	9	12.7	11	118.5
1966	71.7	54	34.2	26	12.7	10	13.3	10	131.9
1967	85.3	55	39.4	26	14.8	10	15.0	9	154.5
1968	94.9	55	44.8	26	17.8	10	15.0	9	172.5
1969	99.4	54	50.7	27	19.2	10	16.4	9	185.7
1970	98.0	50	56.8	29	22.6	12	18.5	9	195.9
1971	95.8	45	69.7	33	26.8	13	20.1	9	212.4
1972	103.2	44	78.6	34	32.6	14	18.5	8	232.9
1973	105.3	41	89.4	35	40.2	16	20.5	8	255.4
1974	110.3	40	104.2	37	41.5	15	22.3	8	278.3
1975 (E)	121.1	37	131.7	41	47.0	15	23.9	7	323.7
1976 (E)	136.1	38	147.0	41	50.8	14	27.1	7	361.0

* Primarily Net Interest Paid

Source: Special Analyses, Budget of the United States Government, Fiscal Year 1976 government purchases and increasing transfers as an instrument of public policy for creating jobs. Conceptually this is not sound policy for it is a fact that, ceteris paribus, government purchases evoke a greater impact on employment than transfer payments. Thus, if the sole purpose of a government program is that of creating jobs, the efficient approach in most instances is through direct purchases.

The reasons for this are explained in some detail in the Appendix and won't be developed at length here. Quite simply, however, the full amount of an increment of government purchases, say $1 million, increases the direct demand for goods and services and therefore increases GNP by exactly $1 million. As a result, direct employment is created in delivering the $1 million of final goods and services to the government. A multiplier effect then takes hold. As this $1 million is respent by its recipients, additional indirect jobs are created. A third round of spending will, in turn, cause even more indirect jobs. There are leakages in the secondary, tertiary and subsequent rounds of spending that ultimately bring an end to the rise in total employment. But the working of the employment multiplier creates total employment effects in excess of the direct employment occasioned by the initial $1 million outlay.

A somewhat smaller level of total employment tends to be created by transfer payments because the initial injections of spending are smaller. Recipients of $1 million in transfers will probably spend most of it on goods and services. However, portions of the transfer payments will find their way into personal savings. Thus some percentage of the original $1 million, say 10%, has leaked from the spending stream at the initial round of spending. So now rather than $1 million calling forth goods and services, creating direct jobs, and setting off a chain reaction of secondary buying and indirect jobs, only $.9 million is injected into the spending stream. Thus, transfer payments tend to create less employment than government purchases simply because the initial increment of spending is lower. Indeed, the Appendix develops the point that multipliers applicable to purchases are theoretically higher by exactly one (e.g., 3 vs. 2, or 4 vs. 3) than those resulting from transfers, and therefore more jobs result from government purchases.

There are caveats associated with this analysis that suggest the multiplier differential in practice is usually less than one. And there is always the question of lag times before the effects of various programs are felt. But nevertheless, the principle that government purchases for space and other purposes tend to create more jobs in the long run than the number created by transfers has fundamental validity. Thus one could argue on this theoretical basis alone that from the standpoint of job creation, spending in support of the space program compares at least favorably with, and probably is superior to, programs implemented by transfer payments.

Having made this argument, the fact still remains that the thrust of this whole debate, precipitated by the space antagonists and skewed to concentrate on the short term, is rather superficial. The basic considerations of the space program as an employment creator are multi-dimensional with respect to depth and breadth, i.e., in terms of the role of space technology in stimulating longer term advances in productivity and economic growth. Thus, if the critics persist in debating the employment generation capability of the space program, the focus should be placed on the stimulative effects of space technology on the economy and how these, in turn, are ultimately transformed into jobs.

SPACE TECHNOLOGY, ECONOMIC GROWTH AND EMPLOYMENT

An understanding of the contributions of space technology to employment levels requires an appreciation of the role technology plays in stimulating improved productivity and economic growth. This is true simply because in an industrial nation, it is fundamentally through technologically-induced economic progress that employment opportunities are increased at rates commensurate with the needs of the labor force while the concomitant desires of society for more leisure time and higher real per capita output are met. This has been the historical secular pattern in the United States. As Boretsky points out,[(2)] American technology caught up with Europe three-fourths of the way through the 19th century, was higher than Europe's by the beginning of this century, and by the end of World War II it had far outdistanced the rest of the world. Its technological prowess was largely responsible for this country becoming the greatest world power - not just militarily, but also economically and politically. And during this entire period, except for cyclical deviations, job opportunities were expanded to meet the requirements of an expanding labor force.

If we are to continue to progress and achieve the goals of full employment and economic stability, the advancement of technology must be facilitated. There is no question that technology and growth generate costs (e.g.,

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[(2)] Michael Boretsky, "Trends in U.S. Technology: A Political Economist's View," American Scientist, Volume 63, January-February, 1975.

pollution, urban decay) as well as benefits to society, and that therefore a balanced growth involving qualitative concerns as well as quantitative considerations is in order. But the space critics, the anti-technologists, and the no-growth advocates have lost sight of two essential facts: 1) without balanced growth, there will be higher unemployment, lower per capita real income, and intensified social turmoil; and 2) technology, including that developed through the space program, is a prime source of growth.

Implicit in the preceding comments are the fundamental arguments favoring the space program as having a more productive role in stimulating employment in the longer term than most of the programs advocated by the critics of space. These arguments can be logically tied to the following syllogistically arranged propositions:

1) Economic progress, defined as increased productivity and higher per capita real (non-inflationary) national income, is necessary to generate adequate employment.

2) Technology is the chief source of economic progress in our advanced economy.

3) Space research and development activity is an important source of technology.

4) Therefore, adequate support to space R&D activity contributes in a significant way to longer term solutions to the nation's employment problems.

There has been extensive research since World War II underlying the first two propositions, and near unanimity exists among economists as to their validity. Significant research since 1970 undergirds the third proposition, and although it is too early to claim unanimity, compelling evidence in its support is rapidly building. One product of this research is a large body of literature documenting the basic validity of these propositions. Therefore the following sections, derived from this documentation, are only expository and are intended to briefly explain in a sequential manner why these propositions are true.

<u>Proposition No. 1</u> Economic progress is necessary to generate adequate employment in the long run.

The basic logic of this principle is clear and should require little elaboration. The fundamental way to provide more jobs and full employment for an expanding labor force is through economic expansion. This can be accomplished primarily by fostering increased productivity. Through improved productivity greater efficiency is achieved in the production process making it possible to reduce costs and prices, increase consumption, expand domestic and foreign markets, and thereby create more jobs and increase overall employment.

On the other hand, a number of potential problems inherently exist in a static economy with a constant real GNP. The undertaking of any new programs, for example, would entail a cutback in labor and other factors of production applied to current programs. More resources for anti-poverty endeavors or pollution control would mean fewer consumer and capital goods. The disruption to established patterns of consumption resulting from allocating a greater percentage of existing resources to social capital would foment social and political turmoil. And most pertinent to the question of jobs, a static economy with a growing labor force would lead to diminishing returns with the ultimate danger of visiting upon our society the scourge of persistent mass unemployment.

Proposition No. 2 Technology is the chief source of economic progress in our advanced economy.

There is no single explanation for the phenomena of productivity increase and economic growth. Determinants are many and complex and include not only advances in scientific and technical knowledge, but a steady growth in the stock of capital per worker, the spread of education, and an expansion of markets making possible specialization and economies of scale. There is no question, however, that technology advances, more commonly referred to as technological change, play a key role. Edward Denison[3], for example, concluded that for the 1948 to 1969 period, about one-half of the four percent growth rate of national income was attributable to quantitative increases in input in the form of labor and capital, and the other half can be ascribed

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[3] Hearings before the Subcommittee on Priorities and Economy in Government of the Joint Economic Committee, Congress of the United States (April 1972), pp 119-120.

to an increase in productivity. By far the most important determinant of the latter, 1.2 percentage points of the four percent growth rate, has been the adoption of new techniques and practices made possible by advances in knowledge, i.e., technology.

The reason for technology's economic leverage can be demonstrated by turning to the basic production function used in many studies. It is expressed in the form -

$$Q_t = A_t f\ (K_t, L_t),$$

where:

Q_t = output in time period_t,

K_t = capital used during time_t,

L_t = labor expended in time_t, and

A_t = level of technology applied during time_t.

This basic equation, which assumes technological progress to be "neutral" in the sense that it affects labor and capital equally and that improvements in the quality of labor and capital are measured as a component of technology, is the fundamental equation used by Solow[(4)] in an earlier landmark study of

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[(4)] Solow, R.M., "Technical Change and the Aggregate Production Function," The Review of Economics and Statistics, August 1957, pp 312-320.

the impact of technology on economic growth. It is particularly noteworthy that here the technology factor, A_t, acts as a multiplier. This multiplicative property of technological progress in augmenting labor and capital is widely accepted in economic research. It suggests that resources allocated to an industry with a high technology factor can provide significantly greater economic leverage than those used in industries with low A_t factors.

On a less esoteric plane, the reason for technology's economic leverage is no mystery, for as suggested in the foregoing, technology is the vital growth component in the other productive factors. Without it, additional increments of land and labor will rapidly become subject to diminishing returns. Land, and the natural resources it embodies, can contribute little to growth unless technology is applied to unlock its riches. The same applies to labor. Some growth can be caused by institutional reorganizations within society which increase the percentage of people usefully employed, and further increments can be achieved by improving labor mobility and thus permitting labor to move from less to more productive industries. But once usefully employed, a worker's physical and mental capacities limit any significant increase in output he may achieve. Therefore, technology advances embodied in the capital goods he uses, and disembodied in the form of improved organizational techniques and managerial methods, become the central factor in increasing his productivity. Worker productivity will not increase by replacing worn-out abacuses and hatchets with new ones. But it will increase by replacing the worn-out abacuses and hatchets with computers and chain saws. In this light, technology is quite obviously the key to winning the race against diminishing returns and to achieving economic progress.

<u>Proposition No. 3</u> Space research and development activity is an important source of technology and, therefore, contributes to longer term solutions to the nation's employment problems.

In considering space R&D as an important source of technology, it is first necessary to state that R&D activity in general is considered by economists to be the major contributor to technological change. A number of researchers have reached this conclusion after discerning positive and statistically significant correlations between the level of R&D activity and advancing technology. One recent comprehensive assessment of this relationship sponsored by the National Science Foundation concluded, for example, that all available evidence on this subject points in a single direction: "The contribution of R&D to economic growth. . .is positive, significant and high."[5] The principal reason for this relationship is that the rate of technological change is to a great degree functionally related to the amount of resources devoted to the improvement in technology, and R&D usually is the primary method available to firms, industries and the nation for channeling its resources to improve technology.

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[5] National Science Foundation, "A Review of the Relationship between R&D and Economic Growth/Productivity," February 1971.

Turning to space R&D, several studies have been undertaken during the past four years to assess the indirect economic effects of the space program on the national economy. Without exception, they have all reached similar conclusions: space R&D has highly stimulative economic effects in terms of (1) promoting higher productivity rates, greater real growth, and an improved trade balance posture; (2) in serving as a partial offset to inflation; and (3) in realizing high rates of return on the investment in the space program.

These general findings were revealed initially in a comprehensive study by the Midwest Research Institute (MRI)[6] during the 1970-1971 period. This was the first major scholarly effort undertaken to understand the indirect contribution of the space program to the national economy, and it concluded that "on the average, R&D expenditures have been an excellent national investment," and that ". . .high technological undertakings, such as the space program, do exert disproportionate weight toward increased national productivity." Subsequent studies[7] of the economic implications of space R&D activity, including several using advanced econometric methods, have reinforced these conclusions.

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[6] Midwest Research Institute, "Economic Impact of Stimulated Technological Activity," Part I, November 1971.

[7] See, for example: Chase Econometric Associates, "Economic Impact of Space R&D Technology," May, 1973; Merz, C.M., Gibson, T.A., Seitz, C.W., "Impact of the Space Shuttle Program on the National Economy," The Engineering Economist, Winter 1973.

The .oot cause of the unusually high economic leverage of space technology is the inherently high technology content of the space program itself. NASA-sponsored R&D activity spans some 33 major technical disciplines within the mechanical, electrical, chemical, aeronautical, materials, and structural engineering fields. And the nation's space activity has precipitated a rapid expansion of our knowledge in these fields. It goes without saying, therefore, that in pursuing its advanced programs, NASA must depend primarily on support from high technology industries. And in allocating its R&D dollars to the more technologically intensive industrial sectors, NASA feeds those innovative industries that generate the technology stimulus our economy must have for improved productivity rates and expanded output. The industrial firms receiving most of NASA R&D funds have a common characteristic: they are capable of advancing technical gains beyond those necessary to meet the immediate requirements of the space program.

It is axiomatic that the proliferation of space technology - in management methods as well as in materials, processes and techniques - would have little secondary value were it not transferred and widely diffused throughout the non-space sectors. For diffusion and subsequent application to take place, there must be efficient technology transfer processes. In the case of the space program, several formal and informal mechanisms have effectively facilitated these processes in response to the mandate in NASA's charter to actively encourage the infusion of space technology into the private sector. These transfer modes range all the way from the formal input and output programs of NASA's Technology Utilization Office, to intersectoral diffusion of space technology through professional societies and the relocation of skilled individuals from the space program to other sectors of the economy. The effectiveness of these well-developed conduits for transferring the technology generated in the space program to nonspace sectors is attested to by the numerous studies conducted to report the technology fallouts and to measure the technology advancements and gains to society which have resulted from the marshalling of resources to meet the goals of the national space program.[8] All have common threads:

1. That immediate returns in medicine, in earth resources measurement and utilization, in communications, in weather forecasting, and in scientific advancement have been of impressive significance.

2. That innovations stemming from space technology will continue for years after the initial technology development.

3. That the indirect effects on the economy with respect to contributing toward increased national productivity, income and employment are quite profound - more so than most other forms of R&D spending.

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[8] See, for example, "Mission-Oriented R&D and the Advancement of Technology: The Impact of NASA Contributions," Denver Research Institute, May 1972.

Proposition No. 4 Therefore, adequate support to space R&D activity contributes in a significant way to longer term solutions to the nation's employment problems.

This proposition is the logical conclusion to be drawn from those proceeding it. Here the reference is not primarily to the scientists, engineers, technicians and others directly involved with the space program - a figure that reached some 400,000 at its peak in 1966 and is less than half that number today. Instead, it is to those jobs that result from the economic progress made possible by technological advance ascribable to space R&D activity.

This proposition should be further clarified lest the direct contributions of the space program to improved productivity and higher employment in the long run are overlooked. The foregoing has inferentially, at least, stressed the spin-off technology. But there are very significant direct contributions being made to increased efficiency and higher productivity. Examples are plentiful. The introduction of communication satellites has vastly improved the productivity of segments of the communication industry. The result has been lower costs to the industry and the public. Prior to the Early Bird satellite (Intelsat I), the charge for leasing a voice grade half circuit between New York and Europe was $10,000 per month. By January 1974, the charge for the same capability had been reduced by more than 50 percent to $4625.

Broadcast satellite technology is also being applied in an on-going effort to improve productivity in the fields of education and public health. NASA's sixth Advanced Technology Satellite (ATS-6) is being used on an experimental basis to extend the reach of medical doctors in metropolitan areas to remote and sparsely populated regions. In like manner, the skills of teachers are being extended to students in remote areas through use of television broadcasts originating in population centers.

As the space program moves into an era of exploitation, where greater emphasis will be placed on applications of space technology to help solve the problems of life on Earth, the direct contributions to greater efficiency and higher productivity will become more apparent. One important area, for example, is earth resources where the use of remote sensing techniques from space as a tool to monitor and manage earth resources looks highly promising. The Space Shuttle will also make a major contribution in that it represents a giant step forward in increasing the productivity of launch systems and the overall efficiency of the space program. Lower launch and payload costs made possible by the Shuttle will make more resources available for improved earth applications and other payloads designed to benefit conditions on earth.

The combined economic leverage of the direct and indirect applications of space technology, then, give credibility to the final proposition. If one accepts the need for balanced economic growth to achieve full employment, and recognizes the vital role of technology in the growth process and space R&D as an important source of that technology, then he must surely embrace the conclusion of this proposition - adequate support to space R&D activity does contribute in a significant way to longer term solutions to the nation's employment problems.

ALTERNATIVE USES OF SPACE R&D RESOURCES

Most who criticize the space program as being relatively unproductive, or urge its reduction and delay while the nation tries to ride out the current economic storm, recommend a redistribution of funding from space to the programs they support. Inevitably they argue that with less spent on space, more will be spent on their programs and inferentially, of course, the interests of the nation's full employment goal will thus be better served. The more substantive portion of this argument - that the nation's full employment goal will be better served - has already been answered in the preceding sections. But even the view that lower funding for space will somehow result in higher funding support to other programs is not borne out by the facts.

Shifting Space R&D to Nonspace R&D Programs

One group of critics doesn't overtly disparage R&D activity per se, but urges that funds be shifted from space to nonspace R&D activities of a civilian nature as a means of obtaining more benefits. But the budgetary process simply doesn't work that way. The executive branch typically recommends and the Congress appropriates funds for programs with defined objectives, such as building highways, landing man on the moon, or providing food stamps to those in need. These programs may or may not have a high R&D content - if they do, then R&D levels are increased and vice versa. The point is that seldom, if ever, does either branch support spending for R&D simply to support science and technology.

It is doubtful, therefore, that any specific reduction of R&D funds for the space program would automatically be applied to R&D effort associated with nonspace programs. As a matter of fact, the significant shift in the composition of the Federal budget in recent years in favor of direct benefits to individuals has been in transfer payments, most notably in income security and similar programs. (See Table 1). The agencies responsible for these programs, of course, are not heavy R&D users. Agencies like the Social Security Administration and the Veteran's Administration devote only a minuscule part of their budget to R&D.

The effect of the shift in priorities implies a general reduction in government funding for scientific and technological activities. And that is exactly what has been happening in recent years. Federal R&D expenditures as a percent of the total Federal outlays fell from 12.4 percent in 1965 to 6.5 percent last year. In constant 1958 dollars, Federal R&D expenditures were lower in 1974 than in 1965 by some $2 billion. It can be assumed that if further expansion in the budgets of the civilian nonspace agencies continues to be dominated by transfer payments and other government purchases, the role of government as a patron of science and technology is likely to diminish. And, since it's highly unlikely that this diminution can be offset by private R&D, the implications are most disconcerting. There was a marked slowdown in the rise of productivity in this country starting in the latter 1960's to about half the previous rate. In the eyes of many economists, it is more than mere coincidence that this occurred as spending for R&D leveled out in the mid-1960's and then began declining as a percent of GNP from 3 percent in 1965 to 2.2 percent last year.[(9)]

Diverting Resources from Space to Social Programs

More vociferous than the group calling for a reallocation of R&D funds in supporting science and technology are those who urge that resources devoted to the space program be diverted to more pressing social problems. This view was dramatically portrayed by representatives of the poor and their mule-drawn wagon train at Cape Kennedy for the first Apollo launch to take man to the moon. The premise for this position is the belief that if the United States can successfully put a man on the moon, it can, with the same amount of money, eliminate poverty, or provide enough jobs for the unemployed, or cure similar social problems. There is, of course, no logical basis for this view if for no other reason than the fact that most such problems require political and economic rather than technical solutions. Coupled with this view is the deep-seated notion that resources devoted to

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[(9)] See, for example, An Interview with John W. Kendrick, U.S. News and World Report, March 24, 1975, pp 58-62.

space should be diverted to "more important" social problems.[10] The corollary, of course, is that the space program of the past has been implemented at the expense of solving the more fundamental social and economic problems of our nation.

It is highly unlikely, however, that spending for space has diverted funds from social programs. From FY 1966 to FY 1974, annual Federal outlays for income security alone rose from $28.9 billion to $84.4 billion, and they are expected to reach nearly $107 billion in FY 1975. Outlays for health have risen from $2.6 to $22.1 billion over the same period, and those for education and manpower from 4.1 to 11.6 billion - and each of these categories will also be significantly higher in FY 1975. Faced with evidence of this type, it is exceedingly difficult to validate the claim that the civilian space program, with outlays of about $3.0 billion in FY 1974 - down from $5.8 billion in 1966 - has reduced support to the anti-poverty or other social programs. If this is the case, how can one account for essentially the same level of space expenditures in FY 1975 as last year, while the combined outlays for health and income security will have increased by some $27 billion in the same one year period?

It is, perhaps, necessary to reiterate once again that the views expressed here are not intended to disparage the merits of these programs, but rather to discredit the protestations of the critics who, in attacking the space

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[10] Holman, Mary A., "The Political Economy of the Space Program," Pacific Book Publishers, Palo Alto, California, 1974, p. 347.

program, use arguments with little or no merit. It makes little sense, indeed, to ignore the basic fact that high technology activity like the space program results in long term productivity gains, and most of the national poverty and similar programs do not. Therefore, public policy makers must realize that the future should not be mortgaged for the sake of short term expediency, that we must have a balanced approach that considers avoidance of future problems even as it considers solutions to current problems, and that current actions must be tempered with the need to leave to future generations the legacy of a viable economy not wracked by massive unemployment and extensive poverty.

This is the message implicit in Holman's argument when she states that we should realistically view poverty and related programs as pure welfare expenditures that are normally justified, but that do not ultimately result in an expansion in productive capacity. In pointing out that the problem of extreme poverty is becoming an ever-increasing problem of maintaining income and consumption levels of families and individuals who have little prospect of providing self-maintenance, she argued that "To divert resources from the space program and from other activities that increase productivity makes no sense in the long run because it is self-defeating. Productivity gains contribute to economic growth, economic growth contributes to higher levels of national income, which in turn, provides a wider tax base to support larger income and consumption maintenance poverty programs."

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(11) Ibid., p. 348

CONCLUSIONS

This paper has stressed the importance of a balanced approach to solving our nation's social and economic problems so that the future as well as the present is given sufficient attention. It is in this light that the space program should be considered, for it does make major contributions to improving productivity, raising incomes and generating employment. Arguments that space diverts resources from social programs, and that the transfer mechanism is the most efficient technique for meeting job creation objectives, simply lack validity.

Since all economic resources are limited, allocative decisions must be made involving more or less support for alternative programs. Thus, the real costs to society of a decision to commit productive resources to a given program is the value of the sacrificed alternative programs to which the resources could have been applied. Or to put it more succinctly, the social cost of what is done is the value of what might be done instead. Perhaps it is in this sense of alternative opportunities lost, or in the jargon of the economist, opportunity costs, that we should view reductions in spending for space and other high technology programs.

Public programs specifically designed to create jobs for those seeking work are socially desirable if they help to alleviate cyclical unemployment during emergency conditions when unemployment compensation and other traditional compensatory measures are inadequate. But the product of these jobs seldom enhances the nation's productive capacity in the same way that productivity is increased by the output of those employed in high technology pursuits such as space. Beautification projects, for example, may be esthetically and therefore socially desirable, but they are far less economically productive than the improved efficiency and lower costs fostered by communication satellites. If, therefore, the job creation and other social programs are pursued at the expense of the space program or other high technology activity by transferring economic resources from the latter, the opportunity costs are not just the immediate loss of jobs in the space industry, but the potential loss to the nation's productive capacity.

The real future costs to society of transferring productive resources from space, then, are in terms of the adverse effects on productivity, growth and, of course, on future job opportunities. Surely a prudent person must conclude that these costs are far too high to warrant serious consideration being given to a further diminution of the space program.

APPENDIX

THE MULTIPLIER CONCEPT AND ITS APPLICATIONS

The multiplier phenomenon rests upon the fact that an increase in spending in some form stimulates successive rounds of secondary consumption spending so that the resulting increase in income (or output) is some multiple of the original increase in spending. Thus, the multiplier is a coefficient relating an increment of spending to an increment of income. If Y is income and I is private investment spending by business while k is the multiplier, then $k\Delta I = \Delta Y$. Similarly, the results of changes in consumer spending (C) and government spending (G) on income can be expressed as $k\Delta C = \Delta Y$, and $k\Delta G = \Delta Y$, respectively.

The Relationship of Consumption to Current Income

It is important to state at this point that the amount of secondary consumption spending induced by an initial increase in investment, government or consumer spending is intimately related to the consumption function, i.e., the relationship between consumption and current income. More specifically, determination of the multiplier depends on the marginal propensity to consume (MPC), which is defined as the portion of an increment of income that will be spent on consumption rather than saved ($\Delta C/\Delta Y$). Since by definition, (disposable) income not spent is saved, the corollary to the marginal propensity to consume is the marginal propensity to save (MPS), i.e., the portion of an increment of income saved. The equation for the multiplier can either be expressed as $k = 1/1\text{-}MPC$, or since definitially the sum of MPC and MPS must equal one, as the reciprocal o MPS, i.e., k = 1/MPS. These equations simply express the obvious fact that the greater the portion of an increment of income that is spent, the greater the multiplier effects. Although the MPC (and therefore MPS) can conceptually be 0 or 1, in practice the MPC is usually >0 and <1. If it was 1, of course, the multiplier would be infinitely large, and an initial increase in spending would set off an endless expansion of income. But leakages, principally savings, cause MPC to be <1, and the multiplier to be finite.

From the above, it can be seen that if a spending increment of $1000 has an MPC of .75, then the multiplier, k, is determined as follows:

$$k = \frac{1}{1\text{-MPC}} = \frac{1}{1-0.75} = 4, \ \left(\text{or } k = \frac{1}{\text{MPS}} = \frac{1}{0.25} = 4\right)$$

and the ultimate increase in ΔY = 4 ($1000) = $4000. It should be noted that the size of the m ltiplier is directly related to the MPC and inversely to the MPS, thus verifying the assertion that the size of the multiplier is a function of the amount of an addition to income that is spent.

Government Spending vs. Transfer Payments

It is a basic macroeconomic theorem that the government purchases multiplier is greater than the multiplier associated with government transfer payments such as social security, unemployment compensation, and related income security programs. Since government purchases affect national income directly, while transfer payments have an indirect effect, this should not be difficult to accept if one recognizes that government purchases are themselves a part of the demand for goods and services, and therefore have the same multiplier impact as, say, the investment multiplier in the private sector. A \$1000 increase in G, in other words, has an MPC = 1. It calls forth fully \$1000 worth of goods and services and thus creates an initial increase in income of \$1000, which subsequently becomes subject to the effects of some leakage (MPC<1) at each successive level of spending.

Transfer payments, on the other hand, affect national income only indirectly. They tend to have a smaller stimulative impact than government purchases because the initial outlay, i.e., the amount spent by the transfer payment recipient, is subject to a condition where MPC = <1. Thus in comparing equivalent \$1000 increments of government purchases and transfers, the entire \$1000 is spent by the government for purchases, whereas in the case of transfers, except when MPC = 1, some portion of the \$1000 is saved; i.e., not immediately spent on consumption. Since the immediate influence of a \$1000 transfer payment is less than \$1000 due to the savings leakage, it follows that the total impact will also be less.

This total impact for both government purchases and transfers can be determined by applying the multiplier to the immediate change in spending. For government purchases we have:

$\Delta Y = \frac{1}{1-b} \Delta G$, where

ΔY = change in income

ΔG = change in government purchases, and

b = marginal propensity to consume (MPC).

For transfers[1], since it can be assumed that fractions of transfer payments leak into savings, we have:

$$\Delta Y = \frac{1}{1-b}(b\Delta Tr) = \frac{b}{1-b}\Delta Tr, \text{ where}$$

ΔTr = change in transfers.

The multiplier effect of a change in transfers is, therefore, smaller in size than the effect of a change in government purchases. In fact, it can be shown algebraically that the government purchases multiplier is exactly one more than the transfer multiplier. If b (the marginal propensity to consume) is 0.75, the purchases multiplier is 1/1 - 0.75 or 4. The transfer multiplier, on the other hand, is 0.75/1 - 0.75 or 3. This is always true, for:

$$\frac{b}{1-b} + 1 = \frac{b}{1-b} + \frac{1-b}{1-b} = \frac{b + 1-b}{1-b} = \frac{1}{1-b}$$

As further demonstration, by subtracting the transfer multiplier from the government purchases multiplier, we have:

$$\frac{1}{1-b} - \frac{b}{1-b} = \frac{1-b}{1-b} = 1.$$

It goes without saying that this analysis assumes constancy in the marginal propensity to consume in both cases. It can be argued that in the real world transfers tend to go to lower income groups with higher MPC's, therefore the difference between government purchases and transfer multipliers may be less than one. But even if the MPC of transfer recipients

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[1] The multiplier for tax reductions is theoretically the same as for transfers.

is one, transfer multipliers would just equal the government purchases multiplier. The analysis also assumes no significant time lags in spending in either of the cases, whereas an argument sometimes proffered favoring transfers as having quicker effects is that government purchase programs often require long lead times. Nevertheless, because the initial increase in government purchases gives rise to an increase in output and then induces secondary increases in consumption, while transfers themselves do not give rise to initial increases in output (i.e., $\Delta G > b\Delta Tr$), government purchases tend to have a more stimulative impact.[2]

Employment and Spending Multipliers

The multiplier concepts described above can be referred to as spending multipliers (k) to distinguish them from the employment multiplier (k'). A spending multiplier relates an increase (or decrease) in consumption, investment or government expenditures to the resulting increase (or decrease) in income. Thus, as explained before, a change in government purchases (G) affects income Y as follows: $k\Delta G = \Delta Y$. The employment

---

(2) This assessment ignores the accelerator effects, i.e., the increase in investment spending resulting from the multiplier-influenced increase in consumption spending. Although the accelerator-multiplier interaction is a powerful economic force, failure to consider it here does not alter the analysis, for the same relative results theoretically occur with or without inclusion of the accelerator within the scope of the analysis.

multiplier, on the other hand, relates the increase in primary employment resulting from the spending increase, i.e., employment required to provide the goods and services initially purchased, to the resulting increase in total employment. Thus, if primary employment is N_2 and total employment is N, then $k'\Delta N_2 = N$. Secondary employment (N_3), that created by subsequent rounds of spending, can then be expressed as $N_3 = N - N_2$.

Although income and employment tend to rise and fall together, it is obvious that the two types of multipliers may not be identical, i.e., k and k' are not necessarily equal. The fact that labor productivity and wage rates differ among industries means that equivalent expenditures on different bundles of goods and services are likely to have somewhat different primary employment impacts. The subsequent secondary employment impacts will also tend to be different.

Since employment and income do rise and fall together, however, economists oftentimes assume that $k = k'$ for purposes of more gross analyses without doing great violence to the facts. This practice is admittedly not strictly correct and should not be arbitrarily assumed when specific employment impact assessments of alternative policies are to be made. But it is usually sufficient for purposes of macroeconomic analyses of the type performed in this paper.

Concluding Remarks

A final point is in order. It follows from the above that contrary to popular bel'ef, it is not accurate to conclude that government transfers will ipso facto create more jobs than high technology activities such as the space program. Although transfer payments may go to people with lower incomes, and a given transfer outlay may therefore by divided initially among more people with perhaps higher MPC's than an equivalent outlay for space where the recipients are higher paid on the average, one must not lose sight of the offsetting facts that: 1) government purchase multipliers are inherently higher than transfer multipliers; and 2) space spending contributes to technology advancement and increased productivity which, in the longer run, will foster economic growth and consequently an overall expansion of job opportunities.

G. LINK MARGIN ANALYSIS FOR GEOSYNCHRONOUS PLATFORM STUDY

APPENDIX G:

LINK MARGIN ANALYSIS FOR THE GEOSYNCHRONOUS PLATFORM STUDY

Page

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COMMUNICATIONS LINK ANALYSIS

A study of the power requirements needed to perform five services on a geosynchronous platform has been made. The five services studied were:

1. Direct to the home broadcast television
2. Teleconferencing
3. Personal communications
4. National Information Service
5. Electronic Mail

General ground rules and constraints on the design of the communication systems were:

1. Minimize the cost to the ground system
2. Pointing accuracy to .01 degree on platform
3. Maximum primary power available to all services is 500 kW.
4. Use RF frequency bands allocated to these services by U. S. Government and international agreements (if applicable) to minimize interference

A detailed analysis of the link calculations and results are as follows (see Figure 1).

<u>Service: Personal Communications (See Figure 2)</u>

This service allows the user to communicate, via a handheld transmitter/receiver or telephone, with any other service subscriber. The user contacts a switching/billing center which then relays the call on to its destination. For ease in identification and billing, a digital modulation technique is used - QPSK Variable-Slope Delta Modulation. For this modulation scheme, a C/N_0 = 9.7 dB gives a bit error rate BER = 10^{-3}, which is adequate for this study. See Noise Budget Parameters, Table 1.

Constraints on the handheld unit are:

1. Antenna Gain (T_X/R_X) = 9 dBi
2. Transmitter Output Power = 1 Watt
3. Receiver Noise Temperature = 34 dB -°K
4. Pointing Angle (3 dB) = 58°

These constraints cause the link calculations to result in the power budget given in Table 2. It should be noted that the caller must know the area of the person he is calling (similar to telephone area code).

The link calculatiors for the four links (remote unit to spacecraft and reverse; switching center to spacecraft and reverse) are shown in Figures 3 thru 7. It may be seen that the total primary power need by the spacecraft is 129.3 kW at 4 GHz. This value is arrived at by multiplying the per channel EIRP (891 M watts) by 45,000 (the number of users that could call simultaneously) and using a 33 percent dc to RF efficiency. The efficiency is somewhat reduced due to the approximate 6 dB backoff from tube saturation output power necessary in order to reduce the intermodulation within each of the 300 beam driver amplifiers. For 150 channels, each at 890 M watt = 1.07 kW, plifiers are needed. A higher frequency would only increase this total an' therefore, was not desired. A lower frequency (i.e., 900 MHz) would have required a 1.3 foot antenna aperture for the handheld unit for the same gain, also unacceptable.

The number of beams needed is somewhat arbitrary, in that it must still be seen if a large number of beams (i.e., 300) can be constructed - none have been built at the present. The beams would be positioned on the ground in a triangular fashion for optimum ground coverage. Figures 8 and 9 show the effects of antenna gain and frequency used on the number of beams needed for CONUS converage and amount of satellite transmitter RF output needed for the calculated EIRP to the remote (i.e., handheld unit).

It would be possible to use an FM analog system with the same bandwidth and obtain an advantage of 15 dB of SNR by employing companding. However, the C/N is still limited to a 8-9 dB threshold and, therefore, not be much improved over the 10 dB C/N required by the digital system used here. Also, the noise heard by the receiver would be of a different nature (thermal rather than quantization) in an FM system.

Another consideration of the design is the use of high power (1 kW) TWTA's or individual low power (1 watt) solid state amplifiers in the satellite transponder.

If solid state devices were used, then 45,000 amplifiers would be needed - 150 for each beam (for 300 beams). The problem of connection and proper filtration without losses would be a serious problem. One advantage of using separate amplifiers would be that there would be no reduction of carrier power due to multicarrier operation and no intermodulation product power generated (a 6 dB backoff for C/IM and a 4.3 dB multicarrier loss was assumed in the TWTA).

Service 2: National Information Service

This service uses a communications system similar to the personal communications service. The subscriber transmits a question to a switching/billing office by telephone. It is then transmitted via the switching/billing center, to the space platform, where it is relayed to the appropriate information center. The reply is sent in the reverse direction.

Since the voice channel system of the personal communication service will handle each individual querie, the link calculation would not need to be repeated. A digital message of at least 6 Kbps is allowed in place of any one voice channel. For 2400 bps transmission, at least two queries can be transmitted on one voice channel (modulation might be QPSK).

Service 3: Direct Broadcast TV

Direct broadcast TV incorporates a central transmitter for the entire United States, with each home dwelling (apartment/office building) receiving the signal via a rooftop antenna and FM/AM converting receiver. See Figure 10.

The noise budget (see Figures 11 and 12) shows that for an output SNR = 49 dB, a CNR of 10.22 dB is required. For the downlink (i.e., space to home), this requires an S/C EIRP = 68.0 dBW/Chan. This requires a transmitter output of 565 watts (54.8 kW dc per channel input).

Thirty-two beams on a single antenna will cover CONUS. The ground receiving antenna (roof top) is 2.7 feet in diameter, which gives it a 3 dB beamwidth of 2.3 degrees. Higher gain in this antenna would increase the diameter and narrow the beamwidth, making the antenna more expensive and more difficult to point and mount.

For five channels, 274 kW for transmitter power is required by the satellite. See Figure 13. The ground requirements (see Figure 14) are 17.8 watts/channel. It can be seen from Figure 15 that a higher frequency choice would be power prohibitive at the spacecraft (keeping the ground receiver constant).

Service 4: Teleconferencing

It is assumed that this service will be provided to specialized customers (i.e. cost is not the prime objective). Therefore, higher frequencies, which precipitates higher path loss and, hence, higher receive equipment costs, are chosen. The frequency band 40-43 GHz has been used for this study. Figure 16 shows the system configuration. Three antennas, 4.7 feet in diameter, duplexed, giving 53 dB (peak) TX/RX gain are used. Fifty-four beams per antenna, each with footprint of 162 miles, will cover CONUS from Geosynchronous orbit.

For a total of 80 teleconferences, each needing 1068 watts dc (178 watts RF), gives a total of 85,400 watts of S/C prime power. The uplink ground antenna is 4 feet in diameter, with a transmitter of 16.6 watts RF. The receive antenna gain of 51 dB is needed for a noise temperature of 5000°F total. An output SNR of 52 dB is calculated for a 32 MHz RF bandwidth at a C/N system of 13.22 dB. See Figures 17 thru 20.

Service 5: Electronic Mail

Mail will be transmitted from one of 800 Post Office centers via the platform, as shown in Figure 21. The Post Office centers will receive the daily mail from a variety of sources:

1. Directly from customers in paper form
2. From nearby Post Offices via microwave link (already in transmission form)
3. From large customers via microwave or telephone system

After transmission by digital technique (see Figure 22), the letters are converted back to paper form and delivered by Postmen.

A high frequency (20 to 30 GHz) is used so as not to interfere with other services provided by the platform, to keep antenna size small, and because transmission from any one center will not average above 18 seconds, which alleviates the high attenuation probability during precipitation.

For a DC-PSK (phase shift key) modulation scheme, a C/N of 34 dB will yield a bit error rate of greater than 1 X 10^{-5} (Figure 22). The power budget (Figure 23) shows that antenna gains of 55 dB (TX and RX) with 95 (RF) watt ground and 4.3 kW S/C (RF) (13 kW dc) transmitters will be required.

In order to cover all CONUS, a 55 dBi gain antenna from geosynch. orbit has a 125 mile footprint requiring 300 beams. Six antennas with 50 beams on each is used for both transmitting and receiving. Link budgets calculations for this service are shown in Figure 24 and 25.

Service	RF Frequency Band		Antenna Size				Power				G/T		C/N	RF	Spacecraft	
			Ground		Spacecraft		RF		Primary							
	U/L (GHz)	D/L (GHz)	Txmt. (ft)	Rec. (ft)	Txmt. (ft)	Rec. (ft)	Gnd. (Watts)	S/C (Watts)	Gnd. (Watts)	S/C (Watts)	Gnd. (dB/°K)	S/C (dB/°K)	Sys. (dB)	BW (MHz)	Antennas (Qty)	Beams per Unit (Qty)
DIRECT TV	14	11	13	2.7	20.2	15.4	17.78 per ch.	18 kW per ch.	534 per ch.	270 kW /5 ch. or 54 kW per ch.	-1.3	18	9.8	32.4 per ch.	1 U/L 1 D/L	32 32
TELECON	43	40	4.0	3.5	4.7	4.7	66.1 per Tele-con	35.6 per Tele-con	200 per Tele-con	85.4 kW telecon or 1068 per telecon	(80 telecons) 13	13	13.2	32.4 per telecon	3 Diplex	54
PERSONAL COMM/NIS (45,000 USERS) TO/FROM REMOTE	4 GHz nominal	4 GHz nominal	.25	.25	60	60	1.0 per ch.	891 mW per ch.	3 per ch.	121.5 kW	-25	27.2	10.4	57	3 Diplex	100
TO/FROM SW CNTR	4 GHz nominal	4 GHz nominal	3.2	6.6	19	19	.110 per ch.	65 mW per ch.	.33	8.8 kW	+5	17.2	12.2	57	3 Diplex	100
ELECTRONIC MAIL (800 CENTERS)	30	20	8	12	12	8	95.5	4.3 kW	286.5	13 kW	21	24	33.8	40	6 U/L 6 D/L	50 50
S/C ELECTRONICS										10 kW						
5-CHANNEL TV 80 TELECONS TOTAL										508.7 kW					23	

Figure 1. Geosynchronous Platform - Summary

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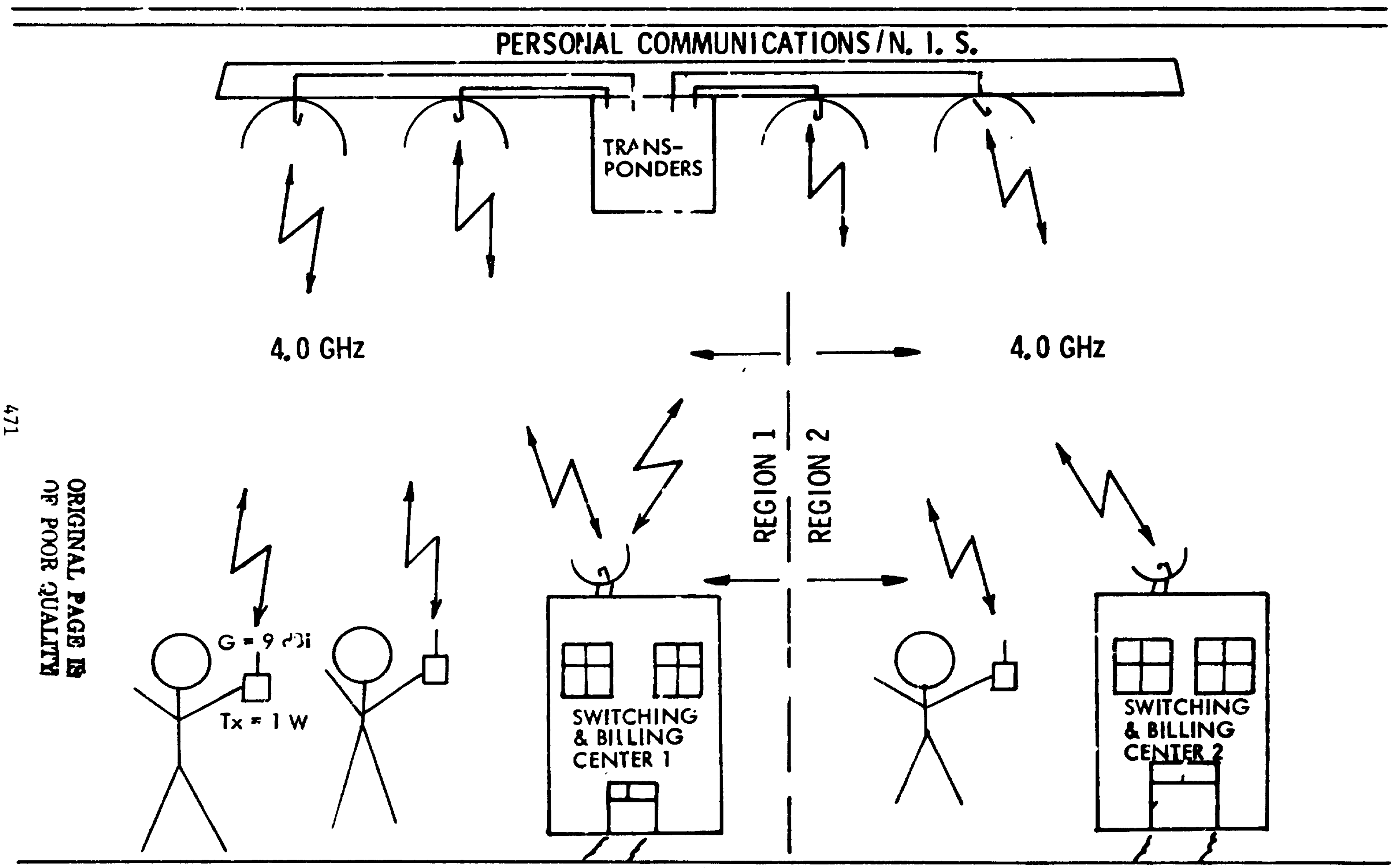
Figure 2 Geosynchronous Platform



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Space Division

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Table 1. NOISE BUDGET PARAMETERS

• MODULATION	QPSK VARIABLE-SLOPE DELTA (COHERENT) - SDMA, SD MULTIPLE ACCESS
• BIT RATE	32 kb/s
• IF BANDWIDTH	19 kHz (42.7 dB)
• TALKER LEVEL	-16 dBm0
• NOISE POWER	8500 pW0p
• BIT ERROR RATE	2×10^{-2}
• C/N_0	53.7 dB·Hz
• S/I	20 dB
• BASEBAND	3.4 kHz (4 kHz NOMINAL)
• $(C/N)_{SYS}$	11.0 dB
• REMOTE T_S	34.0 dB (2512 K) (NF = 9 dB)
• SYSTEM B	19 kHz x 300 CHAN/BEAM x 20 DIFFERENT BEAM FREQ. BANDS = 114 MHz

BER Vs. C/N_0

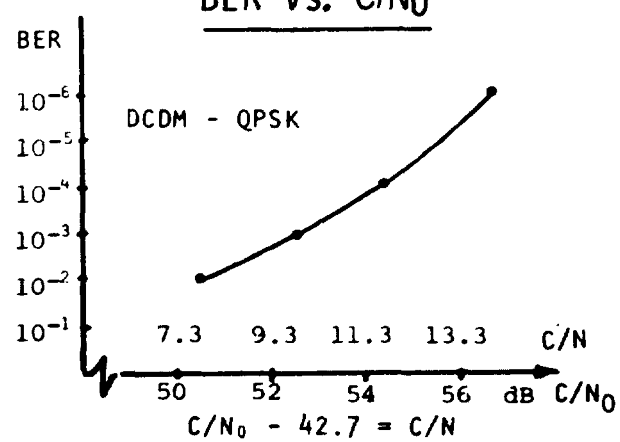

Table 2. Power Budget - Personal Communications

UPLINK BUDGET	REMOTE TO S/C	CENTER TO S/C
RF Frequency	4 GHz	4 GHz
RF Bandwidth/Beam	5.7 MHz	5.7 MHz
Ground Transmitter Output	0 dBw	110 mw/chan
Ground Transmitter Antenna Gain	+9 dBi (3.6")	+30 dBi (3.2')
Ground Antenna Beamwidth	58 degrees	5 degrees
Pointing & Margin Loss	-6 dB	-3 dB
Modem Loss	-1.4 dB	-1.4 dB
EIRP/CARRIER	+1.6 dBw	20.4 dBw
Path Loss	-197 dB	-197 dB
S/C Rx Antenna Gain	(60 foot) 52 dBi (55 dB peak)	42 dBi (45 dB peak)
DOWNLINK BUDGET	**S/C TO REMOTE**	**S/C TO CENTER**
RF Frequency	4 GHz	4 GHz
RF Bandwidth/Beam	2.85 MHz	2.85 MHz
S/C Transmit Output (RF)	891 mw/chan	64.5 mw/chan
Total S/C Primary Power*	121.5 kw @ 32% Effic.	8.7 kw
S/C Transmit Ant.Gain Total	(60) 55 dBi	45 dBi
S/C Footprint Diameter**	(.28°) 130 miles	411 miles
Modem Loss	-1.4 dB	-1.4 dB
Pattern Loss	-3 dB	-3 dB
Margin	-3 dB	-3 dB
EIRP/Carrier	+49.1 dBw	20.1 dBW
Path Loss	-197 dB	-197 dB
Ground Rx Antenna Gain	+9 dBi	+30 dBi
*with voice activation saving	+4.5 dB	4.5
**Beams to Cover CONUS	300	300
Users/Beam	150	15
Total System Users	45,000	45,000
Multicarrier Loss dB	4 dB	
Output backoff	6 dB	

Figure 3. LINK BUDGET CALCULATION

LINK DESCRIPTION PERSONAL COMMUNICATIONS/NIS - UPLINK - HANDHELD TRANSMITTER

$C/N = P_T - L_C + G_{TX} - L_P - L_A - L_E - L_M + G_{RX} - K - T_S - B_{RF} - L_T - L_{POI} - \text{Margin}$

PARAMETER	UNITS	LINK +	LINK -	Σ	REMARKS
Frequency	GHz				
P_T Power Generated	dBw	0			1 Watt
L_C Circuit Losses	dB		0		
L_M Modulation Loss	dB		1.4		
G_{TX} Transmit Antenna Gain	dBi	9.0			D = 3.6"
L_T Pattern Edge Loss	dB		3.0		Beamwidth = 58°
L_{PT} Antenna Pointing Loss	dB		1.0		
EIRP Eff. Isotropic Rad. Power	dBw			3.6	
L_P Space Loss	dB		197.5		
L_A Atmosphere Loss	dB		.2		
G_{RX} Receive Antenna Gain	dBi	55			D = 60 feet
L_C Circuit Loss	dB		.5		
C Carrier Power	dBw			-139.6	
K Bottzmanns Constant	dBw/°K-Hz		-228.6		
T_S Receive Sys Noise Temp	dB-°K		28.5		
B Noise Bandwidth	dB-Hz		42.7		
N Noise Power	dBw			-157.4	
M Margin	dB		3.0	154.4	
C/N Carrier to Noise Ratio	dB			14.8	
$(C/N)_R$ Required C/N	dB			14.8	
C/N Above Margin	dB			0	

LINK BUDGET CALCULATION

LINK DESCRIPTION PERSONAL COMMUNICATIONS DOWNLINK SPACECRAFT TO CENTER

$C/N = P_T - L_C + G_{TX} - L_P - L_A - L_E - L_M + G_{RX} - K - T_S - B_{RF} - L_T - L_{PO1} - \text{Margin} + VA - L_{MC}$

	PARAMETER	UNITS	LINK +	LINK -	Σ	REMARKS
P_T	Power Generated	dBw	-11.9			64.5 MW
L_{MC}	Multichannel Loss	dB		-4.5		
VA	Voice Activation	dB	+4.5			
L_C	Circuit Losses	dB		1.0		
L_M	Modulation Loss	dB		C		
G_{TX}	Transmit Antenna Gain	dBi	45			19 ft.
L_F	Pattern Edge Loss	dB		3.0		
L_{PT}	Antenna Pointing Loss	dB		.5		
EIRP	Eff. Isotropic Rad. Power	dBw			28.6	
L_P	Space Loss	dB		197		
L_A	Atmospheric Loss	dB		.5		
G_{RX}	Receive Antenna Gain	dBi	33			6.6 ft.
L_C	Circuit Loss	dB		1.0		
C	Carrier Power	dBw			-133.9	
K	Bottzmanns Constant	dBw/°K-Hz		-228.6		
T_S	Receive Sys Noise Temp	dB-°K		30.0		
B	Noise Bandwidth	dB-Hz		42.7		
N	Noise Power	dBw			-155.9	
M	Margin	dB	3.0		-152.9	
C/N	Carrier to Noise Ratio	dB			19.0	
$(C/N)_R$	Required C/N	dB			17.0	
C/N	Above Margin	dB			+?.0	

$P_{DC} = 64.5 \times 10^{-3} \times 45{,}000 \text{ Users} \times 1/.33 \text{ efficiency} = 8.8 \text{ kw}$

Figure 4

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LINK BUDGET CALCULATION

LINK DESCRIPTION PERSONAL COMMUNICATION - UPLINK BILLING CENTER TO SPACECRAFT

$C/N = P_T - L_C + G_{TX} - L_P - L_A - L_E - L_M + G_{RX} - K - T_S - B_{RF} - L_T - L_{PO1}$ - Margin

	PARAMETER	UNITS	LINK +	LINK -	Σ	REMARKS
	Frequency	GHz				
P_T	Power Generated	dBw	-9.6			109.6 MW
L_C	Circuit Losses	dB		1.0		
L_M	Modulation Loss	dB		1.4		
G_{TX}	Transmit Antenna Gain	dBi	30			D =3.3 ft.
L_E	Pattern Edge Loss	dB		3.0		
L_{PT}	Antenna Pointing Loss	dB		.5		
EIRP	Eff. Isotropic Rad. Power	dBw			14.5	
L_P	Space Loss	dB		197.5		
L_A	Atmospheric Loss	dB		.2		
G_{RX}	Receive Antenna Gain	dBi	45			19 ft. dia.
L_C	Circuit Loss	dB		.5		
C	Carrier Power	dBw			-138.7	
K	Bottzmanns Constant	dBw/°K-Hz		-228.6		
T_S	Receive Sys Noise Temp	dB-°K		27 8		
B	Noise Bandwidth	dB-Hz		42.7		
N	Noise Power	dBw			-158.1	
M	Margin	dB		3.0	-155.1	
C/N	Carrier to Noise Ratio	dB			16.4	
$(C/N)_R$	Required C/N	dB			16.0	
C/N	Above Margin	dB			.4	

Figure 5

LINK BUDGET CALCULATION

LINK DESCRIPTION PERSONAL COMMUNICATIONS DOWNLINK SPACECRAFT TO HANDHELD UNIT

$C/N = P_T - L_C + G_{TX} - L_P - L_A - L_E - L_M + G_{RX} - K - T_S - B_{RF} - L_T - L_{P01} - \text{Margin} + VA - L_{MC}$

PARAMETER		UNITS	LINK +	LINK -	Σ	REMARKS
P_T	Power Generated	dBw	-.5			891 MW
L_{MC}	Multichannel Loss	dB		4.5		
VA	Voice Activation Imp.	dB	4.5			
L_C	Circuit Losses	dB		1.0		
L_M	Modulation Loss	dB		0		
G_{TX}	Transmit Antenna Gain	dB*i*	55.0			
L_E	Pattern Edge Loss	dB		3.0		
L_{PT}	Antenna Pointing Loss	dB		0		
EIRP	Eff. Isotropic Rad. Power	dBw			50.5	
L_P	Space Loss	dB		197		
L_A	Atmospheric Loss	dB		.2		
G_{RX}	Receive Antenna Gain	dB*i*	9.0			
L_C	Circuit Loss	dB		.3		
C	Carrier Power	dBw			-138.0	
K	Boltzmanns Constant	dBw/°K-Hz		-228.6		
T_S	Receive Sys. Noise Temp.	dB-°K		34.0		
B	Noise Bandwidth	dB-Hz		42.7		
N	Noise Power	dBw			-151.9	
M	Margin	dB	3.0		148.9	
C/N	Carrier to Noise Ratio	dB			10.9	
$(C/N)_R$	Required C/N	dB			10.9	
C/N	Above Margin	dB			0	

$P_{DC} = 891 \times 10^{-3} \times 45{,}000 \times 1/.33 = 121.5 \times 10^3$ watts

Figure 6

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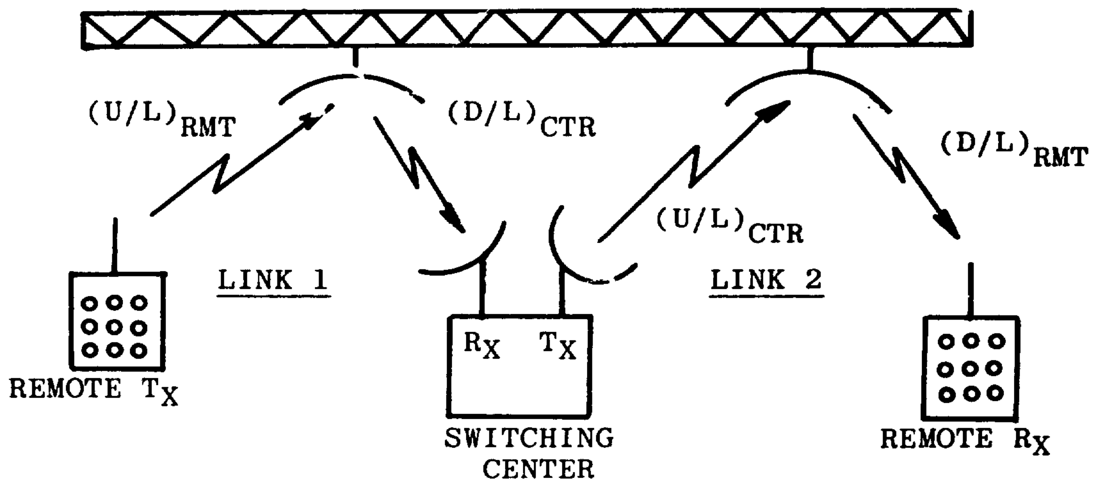
FIGURE 7. PERSONAL COMMUNICATIONS: CALCULATION OF LINK C/N



$$(C/N)_{LINK\ 1} = \frac{(C/N)_{U/L_{RMT}} \times (C/N)_{D/L_{CTR}}}{(C/N)_{U/L_{RMT}} + (C/N)_{D/L_{CTR}}} = \frac{(14.8\ dB)_R \times (17.0\ dB)_R}{(14.8\ dB)_R + (17.0\ dB)_R} = \frac{30.2 \times 50.1}{30.2 + 50.1} = 18.8_R$$

$$= 12.8\ dB$$

$$(C/N)_{LINK\ 2} = \frac{(C/N)_{U/L_{CTR}} \times (C/N)_{D/L_{RMT}}}{(C/N)_{U/L_{CTR}} + (C/N)_{D/L_{RMT}}} = \frac{(16.0\ dB)_R \times (10.9\ dB)_R}{(16.0\ dB)_R + (10.9\ dB)_R} = \frac{39.8 \times 12.3}{39.8 + 12.3} = 9.4_R$$

$$= 9.7\ dB$$

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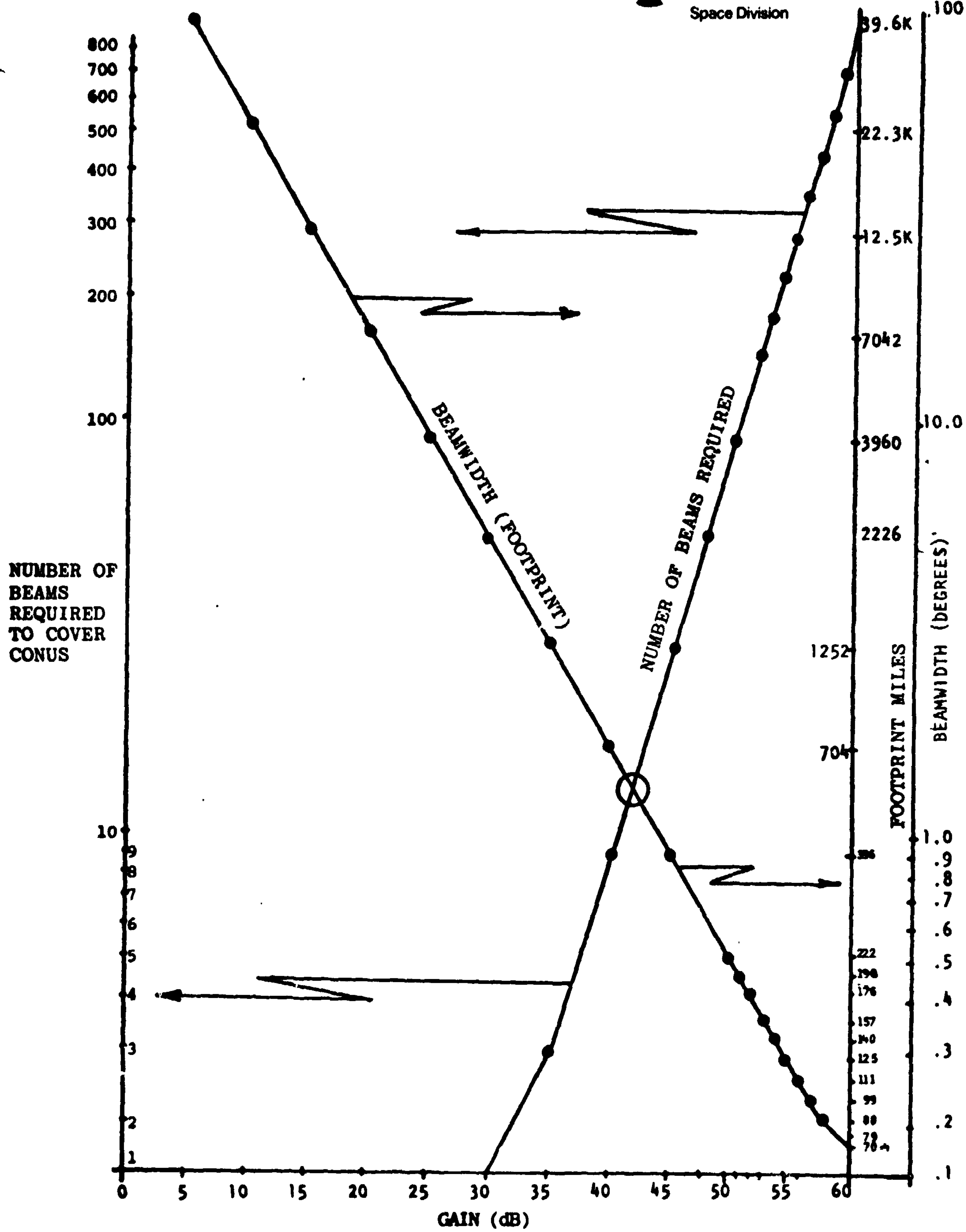

Figure 8. Beams Requir· Versus Antenna Gain

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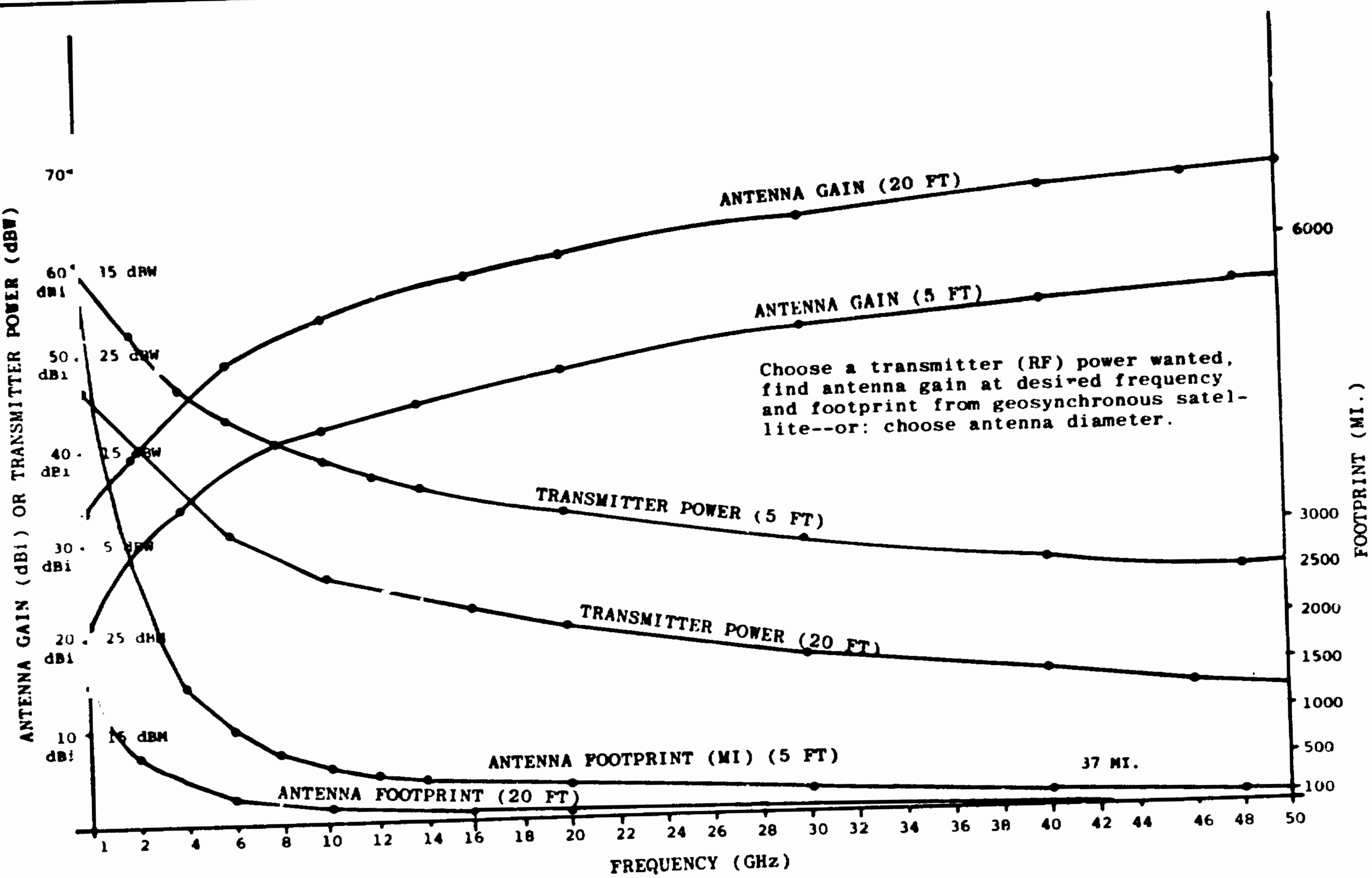

Figure 9. Antenna Gain/Footprint & Transmitter Power (RF) Versus Frequency @EIRP = 55 dBw

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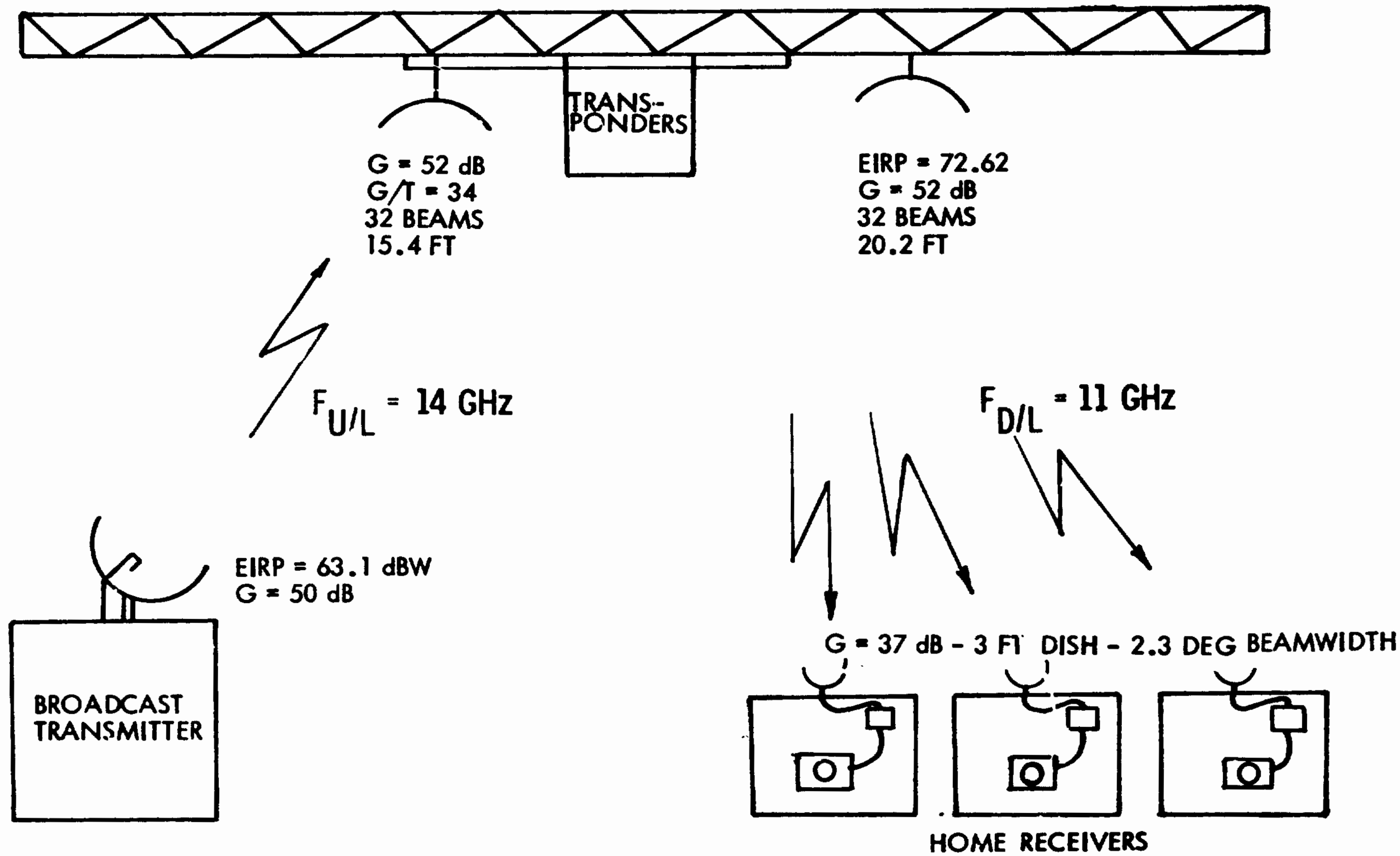
FIGURE 10. GEOSYNCHRONOUS PLATFORM DIRECT BROADCAST EDUCATION*



*WITH HOME FM-AM DEMOD.

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Figure 11. NOISE BUDGET FOR DIRECT EDUCATIONAL TV

• HIGHEST BASEBAND FREQUENCY	4.2	MHz
• OCCUPIED SATELLITE BANDWIDTH	32.4	MHz
• PEAK DEVIATION	12.0	MHz
• MINIMUM S/N (P.P. PICTURE/RMS NOISE)	49.0	dB
• C/KTB UPLINK	15.0	dB
• C/KTB DOWNLINK	11.2	dB
• C/KTB SYSTEM	9.7	dB
• UPLINK FREQUENCY	14	GHz
• DOWNLINK FREQUENCY	11	GHz
• GROUND STATION G/T	-1.3	dB
• SPACECRAFT G/T	+15	dB
• GROUND STATION EIRP	61	dBw
• SPACECRAFT EIRP	68	dBw

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FIGURE 12. SAMPLE NOISE CALCULATION - DIRECT EDUCATIONAL TV

$S/N = (C/N)_{SYS} + 10 \text{ LOG } B_{RF} - 30 \text{ LOG } f_m + 20 \text{ LOG} \Delta f + IF + 10 \text{ LOG } 6$

$(C/N)_{SYS}$	=	9.7 dB	=	CARRIER TO NOISE RATIO IN RF BANDWIDTH
B_{RF}	=	32.4 MHz	=	$2(\Delta f + f_m)$ = OCCUPIED BANDWIDTH
f_m	=	4.2 MHz	=	HIGHEST MODULATION FREQUENCY
Δf	=	12 MHz	=	PEAK DEVIATION OF COMPOSITE SIGNAL
IF	=	13 dB	=	PRE/DE-EMPHASIS AND WEIGHTING IMPROVEMENT FACTORS
10 LOG 6	=	7.78 dB	=	SCALING FACTOR $\left(\frac{\text{Test Tone}}{\text{Noise}}\right)_{RMS}$ to $\left(\frac{\text{Peak In Min.}}{\text{rms Noise}}\right)$

$S/N = 9.7 + 75.1 - 198.7 + 141.6 + 13 + 7.78 = 48.48 \text{ dB}$

LINK BUDGET CALCULATION

DIRECT EDUCATIONAL TV DOWNLINK TO GROUND RECEIVER

$C/N = P_T - L_C + G_{TX} - L_P - L_A - L_E - L_M + G_{RX} - K - T_S - B_{RF} - L_T - L_{POI} - \text{Margin}$

	PARAMETER	UNITS	LINK +	LINK -	Σ	REMARKS
RF	Frequency	GHz			11.0	K-Band
P_T	Power Generated	dBw	27.5			565 watts
L_C	Circuit Losses	dB		1.0		
L_M	Modulation Loss	dB		0		
G_{TX}	Transmit Antenna Gain	dBi	45			Dia.= 202', .9° Beamwidth
L_E	Pattern Edge Loss	dB		3.0		
L_{PT}	Antenna Pointing Loss	dB		.5		
EIRP	Eff. Isotropic Rad. Power	dBw			68.0	
L_P	Space Loss	dB		205		
L_A	Atmospheric Loss	dB		.2		
G_{RX}	Receive Antenna Gain	dBi	35.8			2.3 feet
L_C	Circuit Loss	dB		2.0		2.3° Beamwidth
C	Carrier Power	dBw			-103.4	
K	Bottzmanns Constant	dBw/°K-Hz		-228.6		
T_S	Receive Sys. Noise Temp.	dB-°K		35.8		R_X N.F.= 11 dB
B	Noise Bandwidth	dB-Hz		75.1		32.4 MHz
N	Noise Power	dBw			-117.9	
M	Margin	dB		3.0	-114.9	
C/N	Carrier to Noise Ratio	dB			11.5	(C-N)
$(C/N)_R$	Required C/N	dB			11.22	
C/N	Above Margin	dB			.28	

P_{DC} = 565 watts X 5 channel X 1/.33 Effic. = 8565 watts/beam
for 32 beams = 274 kw

Figure 13

LINK BUDGET CALCULATION

LINK DESCRIPTION DIRECT EDUCATIONAL TV UPLINK GROUND TO SPACECRAFT

$$C/N = P_T - L_C + G_{TX} - L_P - L_A - L_E - L_M + G_{RX} - K - T_S - B_{RF} - L_T - L_{P0I} - \text{Margin}$$

	PARAMETER	UNITS	LINK +	LINK -	Σ	REMARKS
RF	Frequency	GHz			14.0	
P_T	Power Generated	dBw	12.5			17.78 watts
L_C	Circuit Losses	dB		1.0		
L_M	Modulation Loss	dB		0		
G_{TX}	Transmit Antenna Gain	dBi	53			13 ft. (.4°)
L_E	Pattern Edge Loss	dB		3.0		
L_{PT}	Antenna Pointing Loss	dB		.5		
EIRP	Eff. Isotropic Rad. Power	dBw			61.0	
L_P	Space Loss	dB		207.5		
L_A	Atmospheric Loss	dB		.3		
G_{RX}	Receive Antenna Gain	dBi	55			
L_C	Circuit Loss	dB		1.0		
C	Carrier Power	dBw			-92.8	
K	Bottzmanns Constant	dBw/°K-Hz		-228.6		
T_S	Receive Sys. Noise Temp.	dB-°K		37.0		
B	Noise Bandwidth	dB-Hz		75.1		
N	Noise Power	dBw			-116.6	
M	Margin	dB		3.0		
C/N	Carrier to Noise Ratio	dB			20.8	
$(C/N)_R$	Required C/N	dB			15.0	
C/N	Above Margin	dB			5.8	

Figure 14

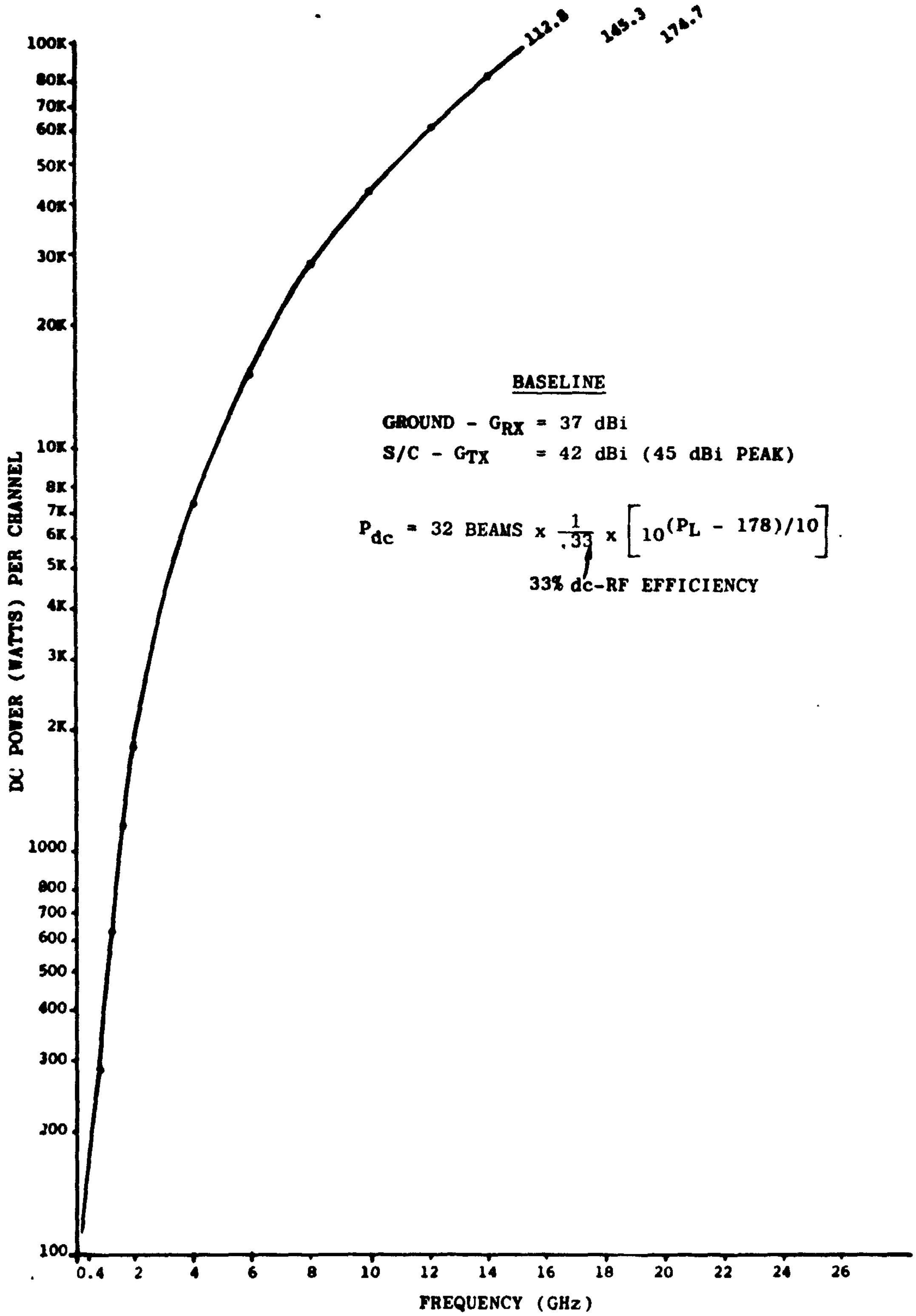

Figure 15. Direct Broadcast TV

FIGURE 16. GEOSYNCHRONOUS PLATFORM: TELECONFERENCING

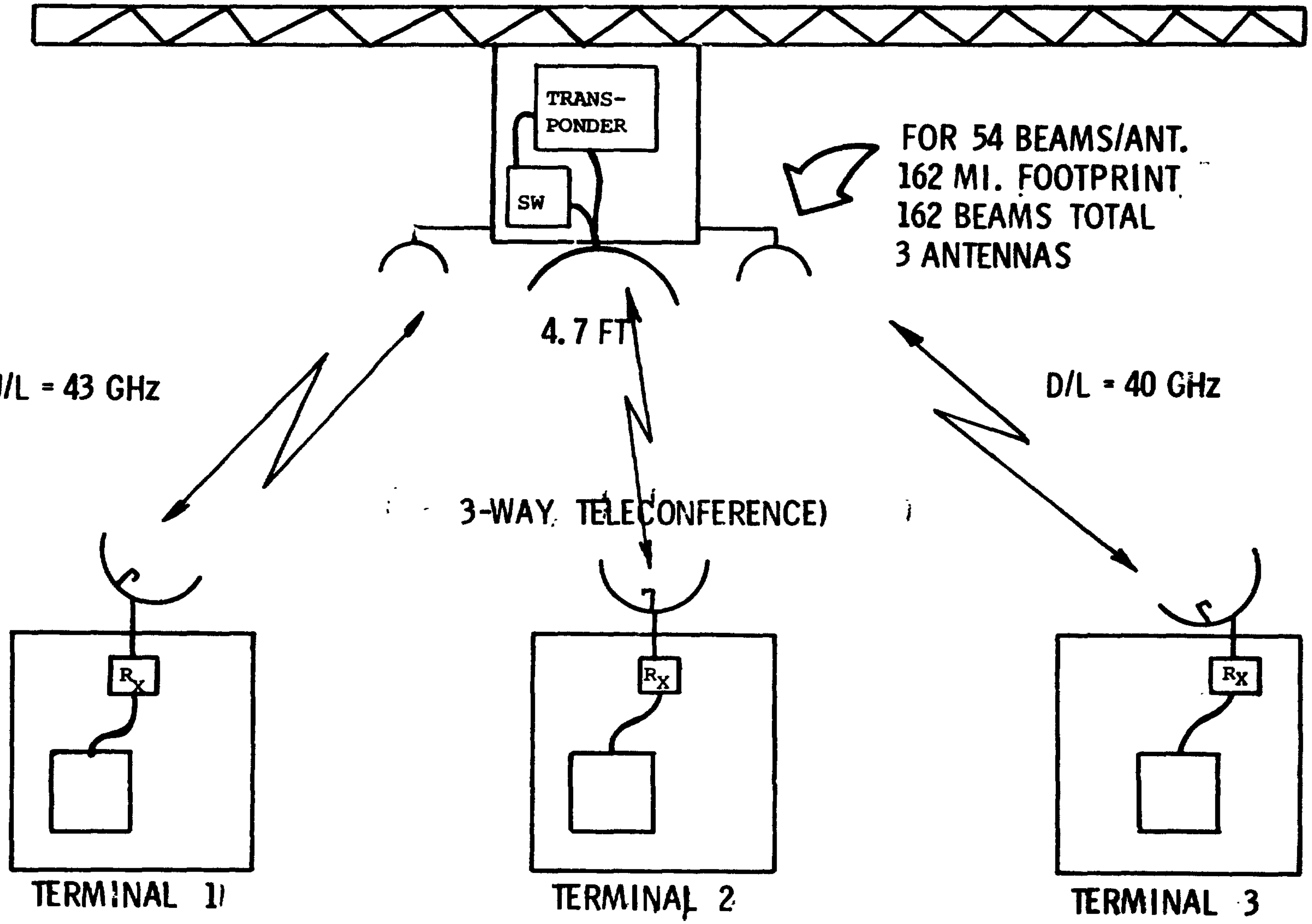

Figure 17. TELECONFERENCING

NOISE BUDGET

BASEBAND FREQUENCY	4.2 MHz
FREQUENCY MODULATION	WB FM
OCCUPIED SATELLITE B.W.	32.4 MHz
CXRS/TRANSPONDER	1
PEAK DEVIATION	12 MHz
MINIMUM S/N_{RMS}	52 dB
GROUND EIRP	66.7 dBw
SATELLITE EIRP	68.0 dBw
$(C/N)_{U/L}$	17.0
$(C/N)_{D/L}$	17.0
(C/N) SYS REQ.	13.22
GROUND STATION G/T	50 - 37 = 13 dB
R.F. U/L FREQ. BAND	43 GHz
R.F. D/L FREQ. GAND	40 GHz
GROUND STATION ANTENNA Rx GAIN	50 dBi (3.5 FT)
(C/N) SYS	17.0
MARGIN	3.78 dB
BEAMWIDTH	28 DEGREES = 120 MI.

Figure 18. SAMPLE NOISE CALCULATION - TELECONFERENCING

$S/N = C/N + 10 \log B_{RF} - 30 \log fm + 20 \log \Delta f + IF + 10 \log 6$

WHERE:

C/N	= 13.22 dB	= SYSTEM CARRIER TO NOISE RATIO
B_{RF}	= 32.4 MHz	= $2(\Delta f + fm)$ = OCCUPIED BANDWIDTH
fm	= 4.2 MHz	= PEAK DEVIATION OF COMPOSITE SIGNAL
IF	= 13 dB	= Pic/De EMPHASIS PLUS WEIGHTING IMPROVEMENT FACTOR

$10 \log 6 = 7.7 dB$ = SCALING FACTOR $\left(\frac{\text{TEST TONE}}{\text{NOISE}}\right)_{RMS}$ TO $\frac{\text{LUMIN. PEAK}}{\text{NOISE RMS}}$

$S/N = 52\ dB = 13.22 + 75.1 - 198.7 + 141.6 + 13 + 7.78$

PRIME POWER CALCULATION
FOR Tx ANTENNA GAIN = 53 dB PEAK
3-dB BEAMWIDTH = .38° ≃ 162-MI FOOTPRINT REQUIRES
162 BEAMS FOR CONUS COVERAGE

FOR 178 WATTS/CHANNEL x 2 CHANNELS/TELECONFERENCE =
356 W/TELECON @ 33% DC-RF

356 W RF x 1/.33 = 1068 W DC/TELECON x 80 TELECONS =
85.440 kW TOTAL PER BEAM

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SAMPLE LINK CALCULATION

LINK DESCRIPTION TELECONFERENCING DOWNLINK

$C/N = P_T - L_C + G_{TX} - L_P L_A - L_E - L_M + G_{RX} - K - T_S - B_{RF} - L_F - L_{POI} - \text{Margin}$

	PARAMETER	UNITS	LINK +	LINK -	Σ	REMARKS
	Frequency	GHz				
P_T	Power Generated	dBw	22.5			178 watts
L_C	Circuit Losses	dB		1.0		
L_M	Modulation Loss	dB		0		
G_{TX}	Transmit Antenna Gain	dBi	50			Dia. = 4.7' (.38°) 163 miles
L_E	Pattern Edge Loss	dB		3.0		
L_{PT}	Antenna Pointing Loss	dB		.5		
EIRP	Eff. Isotropic Rad. Power	dBw			68.0	
L_P	Space Loss	dB		216.5		
L_A	Atmospheric Loss			.5		
G_{RX}	Receive Antenna Gain	dBi	50			
L_C	Circuit Loss	dB		1.0		
C	Carrier Power	dBw			-100.0	
K	Bottzmanns Constant	dBw/°K-Hz		-228.6		
T_S	Receive Sys Noise Temp	dB-°K		37.0		
B	Noise Bandwidth	dB-Hz		75.1		
N	Noise Power	dBw			-116.5	
M	Margin	dB	3		-113.5	
C/N	Carrier to Noise Radio	dB			13.5	
$(C/N)_R$	Required C/N	dB			13.2	
C/N	Above Margin	dB			.3	

Figure 19

SAMPLE LINK CALCULATION

LINK DESCRIPTION TELECONFERENCING UPLINK

$C/N = P_T - L_C + G_{TX} - L_P - L_A - L_E - L_M + G_{RX} - K - T_S - B_{RF} - L_F - L_{POI} - \text{Margin}$

	PARAMETER	UNITS	LINK +	LINK -	Σ	REMARKS
	Frequency	GHz			43.0	
P_T	Power Generated	dBw	18.2			66.1 watts
L_C	Circuit Losses	dB		1.0		
L_M	Modulation Loss	dB		0		
G_{TX}	Transmit Antenna Gain	dBi	53.0			4 feet
L_F	Pattern Edge Loss	dB		3.0		
L_{PT}	Antenna Pointing Loss	dB		.5		
EIRP	Eff. Isotropic Rad Power	dBw			66.7	
L_P	Space Loss	dB		217.0		
L_A	Atmospheric Loss	dB		.5		
G_{RX}	Receive Antenna Gain	dBi	51			3.3 feet
L_C	Circuit Loss	dB		.5		
C	Carrier Power	dBw			-100.3	
K	Bottzmanns Constant	dBw/°K-Hz		-228.6		
T_S	Receive Sys Noise Temperature	dB-°K		37.0		
B	Noise Bandwidth	dB-Hz		75.1		
N	Noise Power	dBw			-116.5	
M	Margin	dB	3		-113.5	
C/N	Carrier to Noise Ratio	dB			13.5	
$(C/N)_R$	Required C/N	dB			13.5	
C/N	Above Margin	dB			0	

Figure 20

FIGURE 21. GEOSYNCHRONOUS PLATFORM: ELECTRONIC MAIL

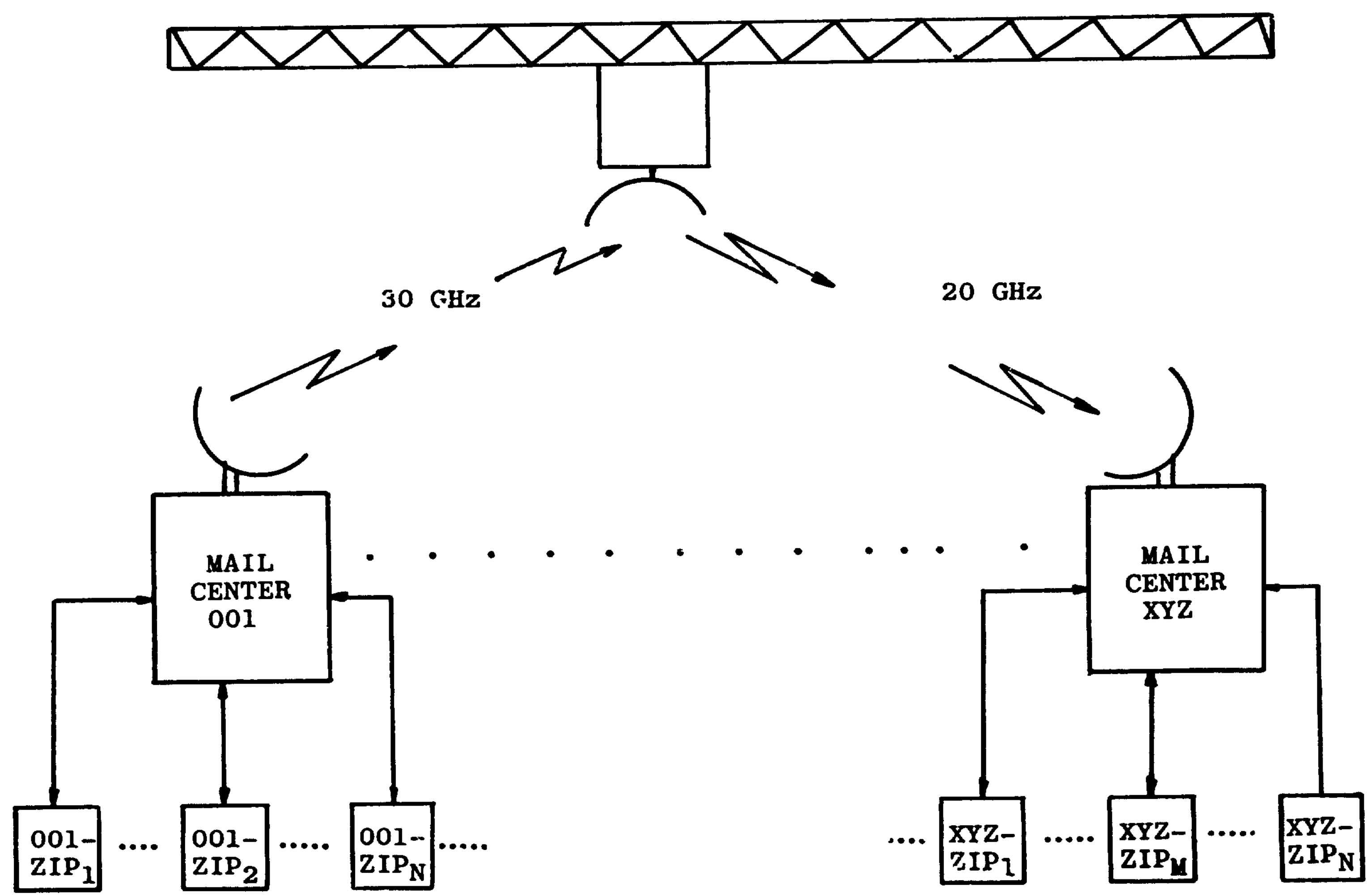

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FIGURE 22. ELECTRONIC MAIL

NOISE BUDGET PARAMETERS

MODULATION	DCPSK
BIT RATE	1.04 MBPS/CENTER
IF BANDWIDTH	1.24 MHz
BIT ERROR RATE	10^{-5}
REQ. E_b/N_o	13 dB
REQ. C/N_{sys}	34 dB
RF BANDWIDTH	80 MHz

$$C/N_{SYS} = \frac{C/N_{U/L} \times C/N_{D/L}}{C/N_{U/L} + C/N_{D/L}} = 33.8 \text{ dB}$$

FIGURE 23. POWER BUDGET PARAMETERS

UPLINK		
RF FREQUENCY	GHz	30
RF BANDWIDTH	MHz	25
GND TRANSMITTER OUTPUT	WATTS	95.5/CHANNEL
GND T_X ANTENNA GAIN	dBi	55 PEAK
GND ANTENNA BEAMWIDTH	DEG	0.28
EIRP/CARRIER	dBW	71.8
PATH LOSS + MARGIN	dB	214
S/C R_X ANTENNA GAIN	dBi	55 PEAK
DOWNLINK		
RF FREQUENCY	GHz	20
RF BANDWIDTH	MHz	25
S/C TRANSMITTER OUTPUT	WATTS	4.3 kW/CHANNEL
S/C PRIMARY POWER	WATTS	13 kW/CHANNEL
S/C T_X ANTENNA GAIN	dBi	55 PEAK
S/C FOOTPRINT DIAMETER	MI.	130
EIRP	dBW	63.6
PATH LOSS	dB	210.8
GND R_X ANTENNA GAIN	dBi	55 PEAK

LINK BUDGET CALCULATION

LINK DESCRIPTION ELECTRONIC MAIL - DOWNLINK

$C/N = P_T - L_C + G_{TX} - L_P - L_A - L_E - L_M + G_{RX} - K - T_S - B_{RF} - L_T - L_{POI} -$ Margin

	PARAMETER	UNITS	LINK +	LINK -	Σ	REMARKS
	Frequency	GHz				20
P_T	Power Generated	dBw	11.6			14.46 w
L_C	Circuit Losses	dB		1.0		
L_M	Modulation Loss	dB		1.4		
G_{TX}	Transmit Antenna Gain	dBi	55			
L_E	Pattern Edge Loss	dB		3.0		
L_{PT}	Antenna Pointing Loss	dB		.5		
EIRP	Eff. Isotropic Rad Power				60.7	
L_P	Space Loss	dB		210.8		
L_A	Atmospheric Loss	dB		.5		
G_{RX}	Receive Antenna Gain	dBi	55			12 ft .28° = 125 mi footprint
L_C	Circuit Loss	dB		.5		
C	Carrier Power	dBw			-96.1	
K	Bottzmanns Constant	dBw/°K-Hz		-228.6		
T_S	Receive Sys Noise Temp.	dB-°K		34		
B	Noise Bandwidth	dB-Hz		60.9		
N	Noise Power	dBw			-133.7	
M	Margin	dB	3		-130.7	
C/N	Carrier to Noise Ratio	dB			34.6	
$(C/N)_R$	Required C/N	dB			32	
C/N	Above Margin	dB			2.6	

Figure 24

LINK BUDG CALCULATION

LINK DESCRIPTION ELECTRONIC MAIL - UPLINK

$C/N = P_T - L_C + G_{TX} - L_P - L_A - L_E - L_M - G_{RX} - K - T_S - B_{RF} - L_T - L_{POI} -$ Margin

	PARAMETER	UNITS	LINK +	LINK -	Σ	REMARKS
	Frequency	GHz				30
P_T	Power Generated	dBw	19.8			
L_C	Circuit Losses	dB		.5		
L_M	Modulation Loss	dB		[illegible]		
G_{TX}	Transmit Antenna Gain	dBi	55			
L_E	Pattern Edge Loss	dB		3.0		
L_{PT}	Antenna Pointing Loss	dB		.5		
EIRP	Eff. Isotropic Rad. Power	dBw			71.8	
L_P	Space Loss	dB		214		
L_A	Atmospheric Loss	dB		.5		
G_{RX}	Receive Antenna Gain	dBi	55			
L_C	Circuit Loss	dB		.5		
C	Carrier Power	dBw			-88.2	
K	Bottzmanns Constant	dBw/°K-Hz		-228.6		
T_S	Receive Sys Noise Temp.	dB-°K		31		
B	Noise Bandwidth	dB-Hz		60.9		
N	Noise Power	dBw			-136	
M	Margin	dB	3.0		-133.7	
C/N	Carrier to Noise Ratio	dB			45.5	
$(C/N)_R$	Required C/N	dB			40.0	
C/N	Above Margin	dB			5.5	

Figure 25

GEOSYNCHRONOUS PLATFORM POWER REQUIREMENTS

Concern has been expressed in the large amount of power required for some of the services performed by the geosynchronous platform. In order to understand the rationale for the large amount of power that must be generated by the platform, the constraints of the system must be known. The primary constraint for the direct educational television service is the low cost and, hence, low performance of the ground receiver.

The performance objective of a communication system is the signal-to-noise (S/N) ratio. Any specified S/N level may be achieved by either increasing the signal power(S) or decreasing the noise level (N). The signal power is directly related to the amount of energy generated at the platform. The noise level is directly related to the noise temperature of the home receiver.

To show the effects of lowering the ground receiver noise temperature on the required transmitter dc power at the platform, refer to Figure 26. For a given downlink carrier to noise ratio of 11.5 dB (fixing antenna gains and signal-to-noise ratio), we see the linear relationship between temperature and power. For a decrease of 5.5 dB-degrees Kelvin in receiver noise temperature (from 5750°K to 1540°K), we see a reduction of 33.1 kW of power per channel (166 kW for 5 channels) at the platform.

According to a NASA Lewis report (with 1976 cost data), the price increase for the cooler receiver would be about $100.00 per unit (for buys of one million). That results in a $100,000,000 increase in receiver costs. This must be compared with the savings of 33 kW per channel of solar cells and associated costs at the space platform.

We can also see that the number of channels broadcast by the platform affects the economic tradeoff of ground versus space costs. For only one channel broadcast by the platform, 33 kW is saved for an increase of $100 in ground cost (per receiver). For five channels of TV, 5 X 33 kW = 165 kW is saved for the same $100 per unit receiver increase. We see that for a large number of channels, it becomes more economic to increase ground cost.

Another factor that must be taken into account, when increasing the cost of the ground receivers, is the effect of the receiver cost on the number of expected users. Since the principle aim of the educational TV service is to reach as many customers as possible, the cost must be kept low for high usage.

A comparison of the link budget for COMSAT (a typical small satellite) and the platform concept, illustrates the differences in antenna gains, noise temperatures and required transmit power at the spacecraft. See Figure 27.

The greater power generated by the platform is primarily due to the higher noise temperature of the receiver and lower gain of the receiving antenna. The antenna gain of the platform study is constrained by:

1. Ease of set-up
2. Pointing accuracy required (large beamwidth)
3. Cost
4. Weight/durability

A 2.3 foot dish ground receiver has a 3 dB beamwidth of 2.8 degrees compared to the 5.9 foot dish which has beamwidth of 1 degree.

Cost of an antenna usually varies inversely with the square of the diameter. At $20.00 for a 2 foot dish, this would become about $100.00 for a 6 foot dish. This $80.00 increase per antenna for one million antennas adds $80,000,000 to ground costs. For these reasons, a 2.3 foot dish is considered a fixed parameter for the platform study.

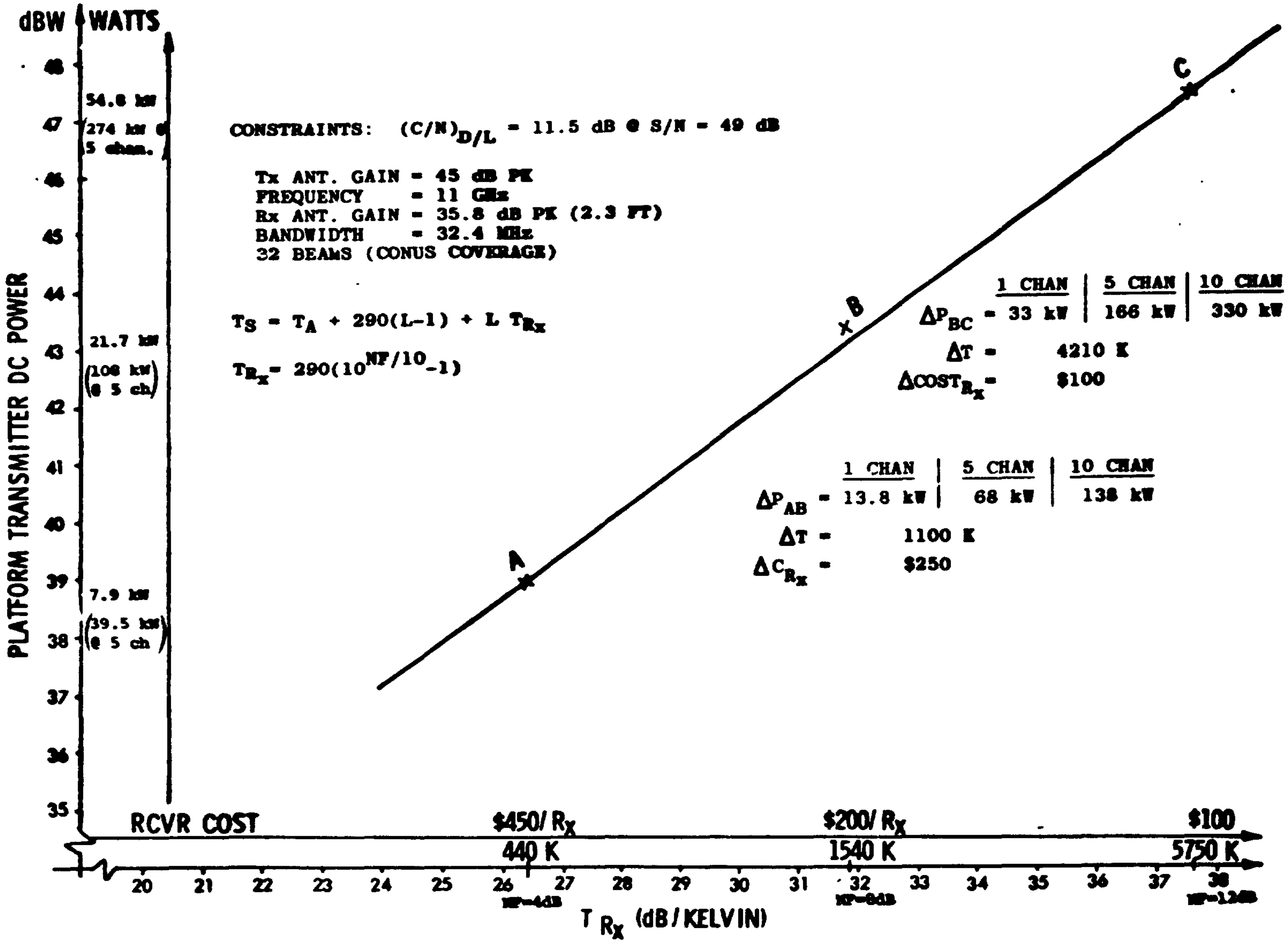

Figure 26. Input DC Power Per Video Channel Versus Receiver Noise Temperature and Cost

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Figure 27. LINK BUDGET CALCULATION COMPARISON

LINK DESCRIPTION

$$C/N = P_T - L_C + G_{TX} - L_P - L_A - L_E - BO + G_{RX} - K - T_S - B_{RF} - L_T - L_{POI} - \text{Margin}$$

	PARAMETER	UNITS	VALUES COMSAT	VALUES PLATFORM	REMARKS COMSAT	REMARKS PLATFORM
	Frequency	GHz	11 GHz	11 GHz		
P_T	Power Generated	dBw	+20.0	+27.5	100 watts	565 watts
L_C	Circuit Losses	dB	-2.0	-1.0		
BO	Backoff	dB	-3.0	0		
G_{TX}	Transmit Antenna Gain	dBi	+37.0	+45	1 Beam National Coverage	32 Beam CONUS Coverage (Individual Beam Control)
L_E	Pattern Edge Loss	dB	-3.0	-3.0		
L_{PT}	Antenna Pointing Loss	dB	0	-.5		
EIRP	Eff. Isotropic Rad. Power	dBw	+49.0	+68.0		
L_P	Space Loss	dB	-205.6	-205.0		
L_A	Atmospheric Loss	dB	-.7	-.2		
G_{RX}	Receive Antenna Gain	dBi	+44.8	+35.8	5.9 ft dia. .9° Beamwidth	23 ft. dia. 2.6° Beamwidth (Easier Pointing)
L_C	Circuit Loss	dB	Included (.5)	Included (1.0)		
C	Carrier Power	dBw	-112.5	-101.4		
K	Bottzmanns Constant	dBw/°K-Hz	-228.6	-228.6		
T_S	Receive System Noise Temp.	dB-°K	+27.8	+37.6	Sys.Temp = 600°K NF = 4 dB	Sys.Temp = 5754°K NF = 12 dB (Lower Cost)
B	Noise Bandwidth	dB-Hz	+75.2	+75.1		
N	Noise Power	dBw	-125.6	-115.9		
M	Margin	dB	+3.0	+3.0		
			-122.6	-112.9		
C/N	Carrier to Noise Ratio	dB	10.1	11.5		
$(C/N)_R$	Required C/N	dB	10.1	11.2		
C/N	Above Margin	dB	0	+.3		
SNR	Required		49.6	48.5		
$(C/N)_{TOT}$	Required		10.1	9.7		
$(C/N)_{U/L}$	Required		*	15.0		
FM	Imp. Factor		39.5	38.8		
DC	Power		100X1/.33 = 303 W/CH.	565X1/.33X32 = 54.788kw/channel		

*C/N Downlink must be greater than 10.1 dB.

APPENDIX H:

ILLUMINATION PATTERNS FOR SUN-SYNCHRONOUS SPACE LIGHT ORBITS

Page

ILLUMINATION PROPERTIES OF SUN SYNCHRONOUS ORBITS

Sun-synchronous orbits are characterized by what may be called *precessional stability*. This means that their rate of precession compensates for the earth's revolution about the sun. Thus, the relative constellation of sun and the orbit remains invariant, as if the orbit was fixed in inertial space with respect to an earth not revolving about the sun. The reflectors are lined up along the orbit at equal intervals at most a few degrees apart. The orbit is a *fixed-in-space* ring with closely spaced reflector units. Within this ring, the earth rotates. A surface point completing one circle at its latitude per 24 hours, faces the orbit, hence, the reflector is in the same position (relative to itself) each night. Orbit position and latitude of the *target* determine the nightly illumination pattern available to the target.

Figure 1 shows the illumination geometry for a typical Lunetta constellation. Assume that the reflectors are used to illuminate the target only within a given elevation angle above the local horizon. Seen from space, the focus of the lowest permissible elevation line is a circle which can be referred to as *useful* illumination area. Larger illumination circles result in a lower *quality* of the light because the Lunetta is nearer to the horizon, hence, the focal area becomes highly elliptic and the path length through the atmosphere increases rapidly. Both factors reduce the total illuminance. The first factor also creates a much larger illumination area than the target area to be illuminated, which reduces the degree of controllability over who does the does not receive light.

While passing through the useful illumination area the target in its center receives light. The amount of light received becomes a maximum if the reflector chain passes through the center of this circle. Shorter transits result in a lower degree of illumination.

The orbit position is given by its inclination (which, in a sun-synchronous orbit is a function of altitude, or vice versa) and the *time* of its maximum latitude. If the time of maximum longitude is midnight, as in the case of Orbit A in Figure 1, then the orbit plane faces the sun as directly as its inclination permits. Figure 1 shows the illumination pattern with Orbit A if the target is at Latitude 1 or 2. In the first case, Illuminance Curve A-1 is obtained. The target within its given useful illumination area receives no light prior to about 21.40. At 22.00 the segmental transit is still very small, so that very little light is received. Within the next two hours, the illuminance level increases rapidly. A maximum is reached at midnight and, thereafter the illuminance declines again in the same way in which it increased before.

If the target is at Latitude 2, however, a different pattern (A-2) emerges. This pattern is more efficient, since the orbit is used twice, yielding maximum illuminance at 22.00 and 2.00. But no light is received at midnight.

Intermediate patterns emerge if the target latitude lies between 1 and 2. Outside this band, which equals the radius of the useful illumination circle,

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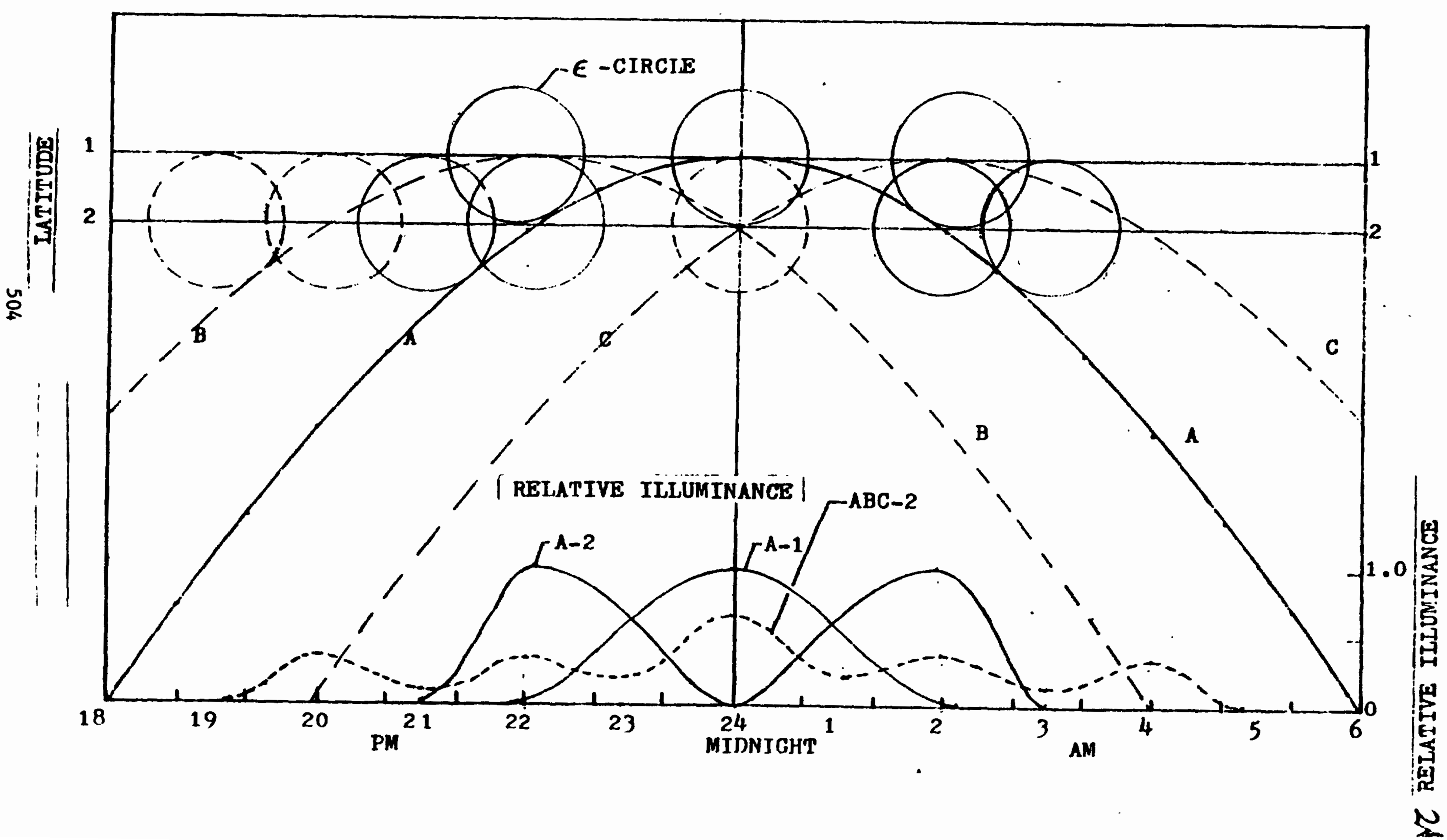
Figure 1. Illumination Pattern Geometry



maximum illuminance cannot be attained at any time. But this example shows that a single illuminance period or two periods can be obtained — and that the interval between the two periods can be selected within certain limits — by properly selecting the maximum latitude (inclination) and the maximum latitude position of the orbit(s) with respect to the target latitude.

This can be useful, especially for Biosoletta illuminating an ocean area to simulate, for example, kelp growth throughout the year. For Lunetta and Powersoletta, these illumination patterns are not likely to be satisfactory.

The illumination pattern can be shaped further by distributing the same number of reflectors over several orbits (co-orbits). Figure 1 shows the case of three co-orbits (A, B and C) illuminating a target at Latitude 2. The resulting pattern yields a more even illumination; however, at a lower level since each orbit now carries only one-third of the lighting power of Orbit A alone. Obviously, if each orbit would carry more than one-third, the pattern would not change, but the illuminance level would be raised. In this case, of course, a large number of reflectors must be installed. It is also possible to influence the illumination pattern by assigning different lighting power levels to each orbit, e.g., 40 percent to B and C each; 20 percent to A.

Thus, for a proven latitude — or for a proven, limited latitude band — the illumination pattern is determined by:

1. The number of co-orbits
2. The time position of their maximum latitude passage
3. The lighting power (number of reflector units) assigned to each co-orbit

The lighting level, of course, is determined by the lighting power in each co-orbit.

The farther north (or south) the target, the higher must be the orbit inclination relative to the equator. The higher the inclination, the lower the altitude of the sun-synchronous orbit; hence, the smaller the illuminated area and the smaller the overall reflecting area.

SPECIFIC ILLUMINATION PATTERNS FOR VARIOUS LATITUDES AND PURPOSES

Because of the large number of variables entering into orbit selection, the selection of the optimum orbit, in terms of inclination/altitude, number of co-orbits and lighting power per co-orbit, is extremely complex and requires specific task definitions.

Nevertheless, it is possible to gain considerable insight by distinguishing between high, medium and low latitudes and by considering three distinct functions — illumination (Lunetta), agricultural/oceanic stimulation (Agrisoletta, not the large Biosoletta, in geosynchronous orbit described previously), and electric power generation (Powersoletta).

ILLUMINATION AT HIGH LATITUDE

For illumination of targets at 50° to 65° latitude, an orbit at $\beta_{max} = 65°$ may be selected. If the Lunetta is used to illuminate not cities but remote industrial (oil, gas, mining) operations in the high north, targets at 70° latitude or higher could be illuminated since multi-directional lighting (along north-south axis) does not appear important in contrast to city illumination.

Figure 2 shows the results of an analysis of a Lunetta system in which the primary function is the illumination of remote industrial activities. The maximum latitude is 65°. Three co-orbits (A, B, and C) with A and C near maximum distance of β_{max}, passage off midnight. Targets at latitude south of 65° receive an illumination peak around midnight. The peak is more gradual closer to 65°. Thus, the illuminance curves for 55° and 50° N would fit a night shift from 22:00 through 2:00. At 60°, higher illuminance is provided from 21:00 to 3:00. If the same profile is desired for locations at 55°, β_{max} should be 60° rather than 65°. The 60° profile can be evened out by lifting the dip around midnight. This can be done by lowering β_{max} for B to 60°. Increasing the lighting power of B would not help, since this would also raise the peaks at 22:30 and 1:30. In fact, it was necessary to lower the lighting power of B in order to avoid greater uneveness in any of the profiles.

The 70° profile shows the comparatively longest period of even lighting. But its overall lower illuminance indicates the fact that diametric transit obviously is not possible for a target latitude above β_{max}. In this profile, the *dip* around midnight could be eliminated by raising β_{max} for B to about 68°.

The illuminance levels of the profiles* are based on the nominal lighting power (maximum illuminance at zenith) of 200, 100 and 200 moons for Orbits A, B and C, respectively. Table 1 shows that this Lunetta would be quite small, especially if the nominal lighting power is based on zenith position on which condition the illuminance in Figure 2 are based. This size would yield almost a 3 σ confidence level for all weather conditions if illuminance levels down to 5 - 10 moons were adequate.

*These and all subsequent values refer to clear night illuminances. Final system sizing must, of course, take cloud coverage into consideration.

Figure 2. Illumination of Area at High Latitude

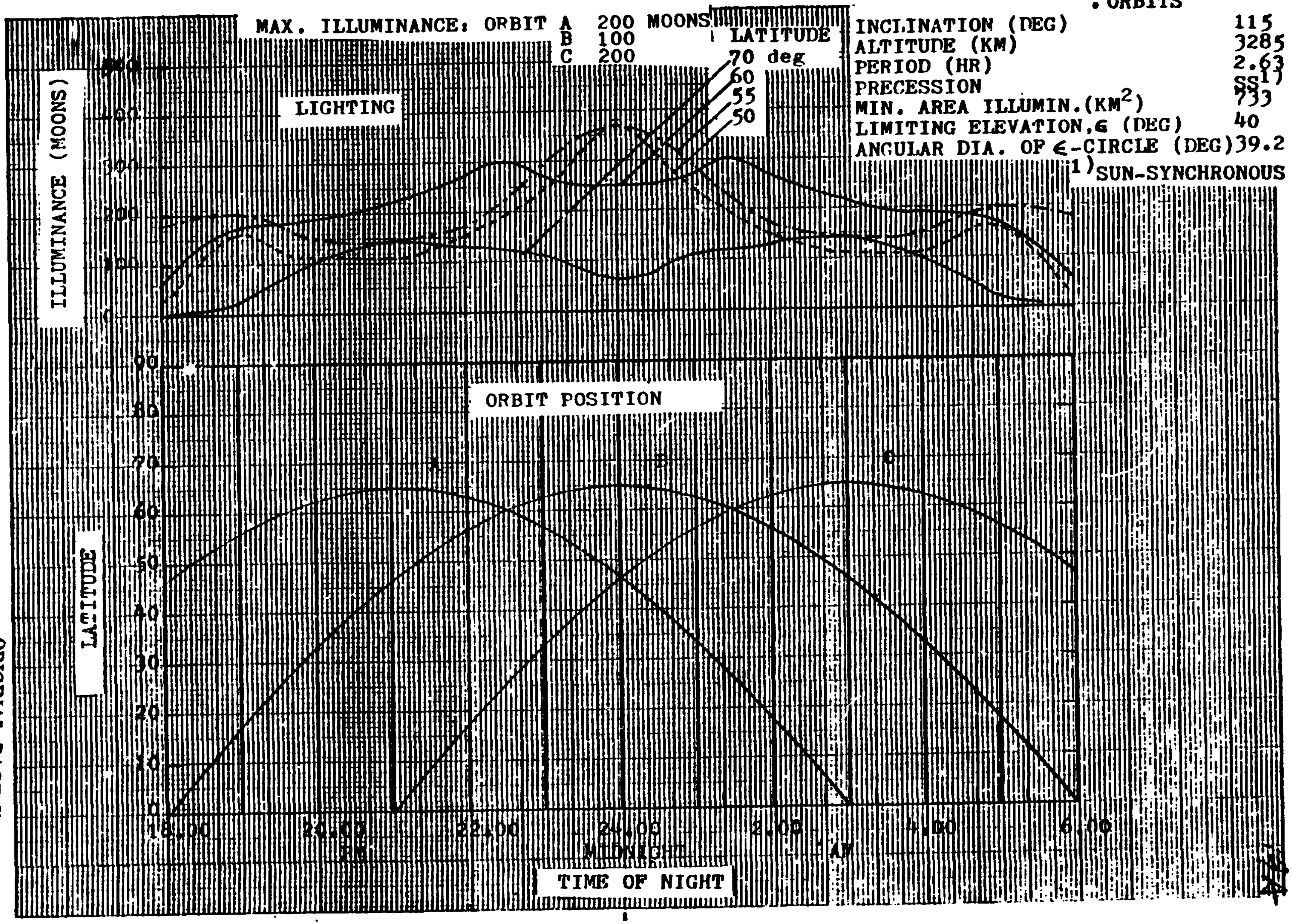


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Table 1. Lunetta for High Latitude Illumination
(Reflectivity ρ = 0.95; Mean Reflection Angle 65°)

ORBIT	A	B	C
Nominal Lighting Power @ Zenith (Moons)	200	100	200
Limiting Elevation Angle, ε_{lim} (Deg)	40	→	→
Diameter of ε-Circle (Deg)	39.2	→	→
Reflecting Area, A_r, within ε-Circle for Above Nominal Lighting Power (km^2)	0.18	0.09	0.18
Total Reflecting Area to Maintain A_r within ε-Circle Continuously, $A_{r,tot}$ (km^2)	1.66	0.83	1.66
If Sized for Nominal Lighting Power Not at Zenith, but at ε_{lim}, then Lighting Power at Zenith Becomes (Moons)	520	260	520
Illuminance Levels in Figure are Raised by Factor	2.6	→	→
$A_{r,tot}$ (km^2)	4.32	2.16	4.32

ILLUMINATION AT MEDIMUM LATITUDE

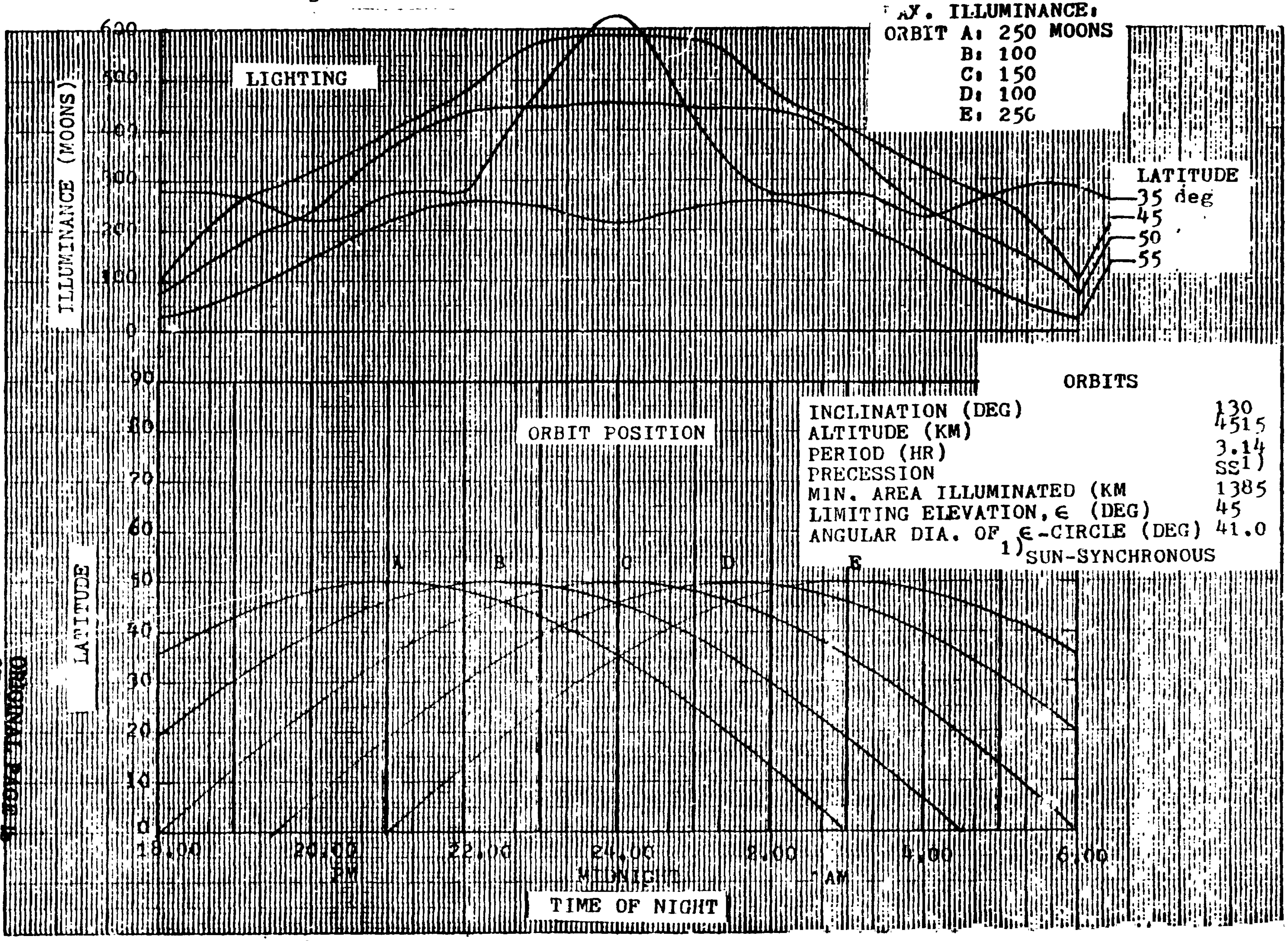
The majority of large cities are located between 50° N and 30° N. This means a Lunetta for illuminating medium latitudes will most likely have the function of illuminating large cities and industrial regions.

In this case, β_{max} should be 60° if major emphasis is placed on the 40° to 55° belt, or 50° if more emphasis is placed on the 35° to 45° region. Moreover, a larger number of co-orbits is required over the maximum turning range of the orbit, to assure a relatively high illuminance level at mid-evening and pre-dawn hours.

Figure 3 shows the results of the analysis of a five co-orbit Lunetta system (Orbits A thru E) with β_{max} = 50° and with particularly strong lighting power in Orbits A and E.

The illuminance profile for a target latitude of 45° N shows strong lighting for most of the night with a broad maximum between 23:00 and 1:00. Illuminance falls off near sunset and sunrise, when the need for Lunetta fades. The profile for a target at 50° (= β_{max}) shows an even broader maximum (22.00 through 2.00). But, the illuminance experiences a fairly steep decline in the pre-dawn hours

Figure 3. Illumination of Area at Medium Latitude



(after 3:00) and is at a correspondingly fairly low level between 20:00 and 22:00. The 35° profile indicates a high and stable lighting level 18:00 - 22:00 and 2:00 to 6:00, which is quite desirable. Around midnight, the light level rises significantly — which is due to the fact that the cross-over point of the two brightest orbits (A and E) occurs over 35° N. The midnight peak recedes between 35° and 30°, that is, for cities such as Los Angeles, Houston and others.

Again, the illuminance levels of the profiles shown in Figure 3 are based on the nominal lighting power of the co-orbits at the zenith of the useful area of illumination. For these conditions, Table 2 shows that the overall reflecting area to be installed in all five co-orbits together is about 12 km^2.

Table 2. Lunetta for Radiuum Latitude Illumination
(Reflectivity ρ = 0.95; Mean Reflection Angle 50°)

ORBIT	A	B	C	D	E
Nominal Lighting Power at Zenith (Moons)	250	100	150	100	250
Lim. Elevation Angle, ε_{lim} (Deg)	45°	→	→	→	→
Diameter of ε-Circle (Deg)	41°	→	→	→	→
Reflecting Area, A_r, within ε-Circle for above Lighting Power (km^2)	0.4	0.16	0.24	0.16	0.4
Total Reflecting Area to Maintain A_r within ε-Circle Continuously, $A_{r,tot}$ (km^2)	3.52	1.41	2.11	1.41	3.52
$\sum A_{r,tot}$ (km^2)			11.97		
If Sized for Nominal Lighting Power at ε_{lim}, then Lighting Power at Zenith (ε = 90°) Becomes (Moons)	508	203	305	203	508
$A_{r,tot}$ (km^2)	7.15	2.86	4.28	2.86	7.15
$\sum A_{r,tot}$ (km^2)			24.3		

As mentioned before, β_{max} should be 60° for primary emphasis on the 40° to 55° latitude band. The profiles would look similar as in Figure 3, but each for a 10° higher latitude. For prime emphasis on the 35° to 50° band, the maximum latitude should be 55°. Most of the major cities in North America, Europe, southern Russia and Japan are located in this belt. Therefore, this maximum latitude was chosen.

I. REFERENCES AND RELATED DOCUMENTS

APPENDIX I:

REFERENCES AND RELATED DOCUMENTS

REFERENCES AND RELATED DOCUMENTS

- General relevant literature pertaining to:
  - Domestic and international economic and demographic statistics (domestic sources, foreign sources, U.N., world bank, etc.).
  - Legal aspects and treaties (space, sea, frequency allocations).
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